PROCEEDINGS OF 2010 JKUAT SCIENTIFIC, TECHNOLOGICAL AND INDUSTRIALISATION CONFERENCE

"Scientific, Technological and Innovation for Industrialisation and Sustainable Development"

17th - 19th November, 2010

SUB-THEME I

BASIC AND APPLIED SCIENCES FOR INDUSTRIALISATION AND DEVELOPMENT

SAOPTIMIZATION OF GROWTH CONDITIONS AND CHARACTERIZATION OF ENZYMATIC ACTIVITY OF SELECTED NOVEL *STREPTOMYCES* SPECIES FROM KENYAN SOILS

E. N. Karanja, H. I. Boga, A. W. Muigai, F. Wamunyokoli, J. Kinyua and J. O. Nonoh
Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: hboga@fsc.jkuat.ac.ke

Abstract
This study was aimed at unveiling and assessing protease, esterase, amylase and lipase enzymes from selected novel *Streptomyces* species with biotechnological interest. Four *Streptomyces* isolates from Jomo Kenyatta University of Agriculture and Technology farm soil were studied. Physiochemical and biochemical characterization of the isolates was carried out. The isolates grew well at pH 6, 7, 9 and temperatures of 27.5 ^{o}C, 30 ^{o}C, and 32.5 ^{o}C. They preferentially required sodium chloride (0 g/l – 17.5 g/l) for growth. All the isolates produced amylase, lipase, protease and esterase enzymes apart from one isolate that did not produce esterase enzyme.

Key words: *Streptomyces,* enzymatic index (EI), amylase, lipase, protease, esterase

1.0 Introduction

Streptomyces spp. are generally soil-dwelling organisms that exist as semi-dormant spores (Mayfield *et al.,* 1972). They are the most important group of the Actinobacteria with high G+C content of the DNA. Morphological characteristic of Streptomyces include growth by vegetative hyphae measuring between 0.5 – 2.0 µm in diameter and production of an extensive mycelia that really fragments. Members of the group produce aerial hyphae bearing chains of conidiospores on their tips when growing on agar resulting to dull, powdery or velvety appearance of the colonies that are difficult to pick from the surface of the agar plates (Kieser *et al.,* 2000).

In 2001, Streptomyces genome was fully sequenced and it was found to have a linear chromosome of 8,667,507 base pairs long and predicted to contain 7,825 genes, about twice as many as typical free-living bacteria, making it the largest bacterial genome yet sequenced. The numbers of antimicrobial compounds that have been isolated and reported from these species have increased exponentially in the two decades as indicated from reports (Watve *et al.,* 2001). Around 23,000 bioactive secondary metabolites produced by microorganisms have been reported and over 10,000 of these compounds are produced by Actinomycetes, representing 45% of all bioactive microbial metabolites discovered (Berdy, 2005).

1.1 Enzymes from Actinobacteria

1.1.1 Proteases

Proteases are the most important class of industrial enzymes as they account for up to 25% of all commercial enzymes used in the world. It is estimated that two thirds of the industrially produced proteases are from a microbial source (Gerhartz, 1990; Moon and Parulekar, 1991). The majority of these proteases are used in food, pharmaceutical and detergent industries. For example alkaline proteases are used in detergent powders, and in food processing, e.g. in production of protein hydrolysate (Phadatare *et al.,* 1993). Acid proteases are used extensively in meat tenderization and in the production of fermented foods by moulds from soybean, rice and others cereals (Nout and Rombouts, 1990). They are also used in the baking industry for the modification of wheat proteins whereas in the dairy industry they are used in the manufacture of cheese (Boing, 1982).

Porto *et al.* (1996) studied *Streptomyces clavuligerus* cultures for protease production. They reported that the amount of enzyme produced varies greatly with the culture media used. An important advantage of these proteases produced from *Streptomyces* is they are secreted into the media and hence can easily be extracted and purified by filtration (Phadatare *et al.,* 1993).

1.1.2 Lipases and Esterases

Microbial carboxylesterases that include lipases (EC 3.1.1.3) and esterases (EC 3.1.1.1), catalyze the hydrolysis of a broad range of natural and unnatural esters, often showing high enantio-selectivity and region-selectivity. To date there are over 70 commercially available lipases that are extracellularly produced by various micro-organisms (Bornscheuer and Kazlauskas, 1999).

Lipids are commonly used as carbon sources in *Streptomyces* fermentation but studies on their esterase and lipolytic activities are largely indescribed (Tesch *et al.,* 1996; Sommer *et al.,* 1997; Abramic *et al.,* 1999). For example cell-bound lipases have been described in only five well-known Streptomycetes such as *Streptomyces clavuligerus*, *Streptomyces lividans*, *Streptomyces coelicolor, and Streptomyces rimosus* and in the related *Saccharopolyspora erythraea* (Large *et al.,* 1999).

1.1.3 Amylases

Starch hydrolyzing enzymes are widely distributed in *Streptomyces* species (Goldberg and Edwards, 1990), and some of them can attack and hydrolyze raw starch granules (Fairbarn *et al.*, 1986), with the release of maltose as the predominant product. Such enzymes are useful for the industrial conversion of raw starch into sugars for fermentation (Norman, 1978). α-Amylase from *Streptomyces praecox* NA-273 (Takaya *et al,* 1979) has been purified and shown to contain three isoenzymes that convert starch to maltose, without formation of glucose (Suganuma *et al.,* 1980). On the other hand, the purified amylase from a chlorotetracycline-producing strain of *Streptomyces aureofaciens* cleaves starch through an endo-mechanism, producing glucose, maltose and maltotriose in α-configuration as main products (Hostinova and Zelinka, 1978).

The importance of the microorganisms in enzyme production is due to high production capability, low cost and susceptibility to genetic manipulation. Actually, the enzymes of microbial origin have high biotechnological interest such as in the processing of foods, manufacturing of detergents, textiles, pharmaceutical products, medical therapy and in molecular biology (Pilnik and Rombouts, 1985; Falch, 1991; Rao *et al.,* 1998). Knowledge of the spatial and temporal variation of enzymes in such ecosystems, the organisms producing the different enzymes and factors affecting enzyme activity are important to understand. Besides this, industrially useful enzymes with novel applications, or which improve upon the activities of ones being currently used, are frequently being sought (Marrs *et al*., 1999). The aim of this study was to unveil and assess amylase, lipase, protease and esterase enzymes from the isolates that could be of commercial importance hence improving industrial and pharmaceutical applications as well as other sectors where they may be of use.

2.0 Materials and Methods

2.1 Growth of Actinobacteria isolates

Five *Streptomyces* species isolates from International Centre for Insect Physiology and Ecology (ICIPE) microbial bank with biotechnological interest were used. Four of the *Streptomyces* isolates were from Chyulu National Park (Chy 4-10, Chy 15-10, Chy 15-5 and Chy 2-3) and one from Ruma National Park (Ruj 7-1).

The isolates were fermented in a differential broth media in a shaker incubator (Gallen Kamp, Germany) (200 rpm, 28ºC) for 96 h. The original stocks of the isolates from which the working stocks were prepared were kept in a freezer (Sanyo MDF-594 AT, Japan) at - 80°C.

2.2 Physiochemical characterization of the Actinobacteria Isolates

In order to carryout screening of enzymes from the isolates, optimization of growth conditions and media composition was done to achieve good results.

2.2.1 Effect of pH on Growth of the Actinobacteria Isolates

An optimum pH requirement for the isolates was determined. International Streptomyces Project (ISP_2) broth media adjusted to varying pH ranges of 3, 6, 7 and 9, using 1N sodium hydroxide and 1N hydrochloric acid was used. The cultures were incubated in a shaker incubator (Gallen Kamp, Germany) (30ºC for 48 h at 100rpm) and optical density readings were read at 600nm using a UV spectral photometer (Shimadzu UV 240, Japan).

2.2.2 Effect of Temperature on Growth of the Actinobacteria Isolates

Growth of the five isolates was monitored by spectrophotometric measurement of the optical density at 600 nm. Experiments were performed at 15, 20, 25, 27.5, 30, 32.5, 35, 36, 37, and 38°C. Prior to the

experiments, bacteria were acclimatized to the temperature conditions in the growth experiments. All cultures were grown in liquid International Streptomyces Project (ISP_2) media on a rotary shaker incubator (Gallen Kamp, Germany) (15, 20, 25, 27.5, 30, 32.5, 35, 36, 37, and 38°C for 12 h at 100 rpm) in the dark. Precultures of acclimatized strains that were used for setting up growth experiments were grown overnight. Experiments were performed in 100-ml Erlenmeyer flasks in triplicate for each isolate. The medium used for the experiments was preincubated in a flat bed incubator for 6 h under the same temperature conditions as the temperature conditions in the experiment. Measurement of the optical density was started 72 h after inoculation. The optimal growth temperature was determined graphically.

2.2.3 NaCl tolerance Test

For this test, NaCl broth was used. 50 ml of the medium was autoclaved at 121°C for 15 min in clean 100 ml conical flasks. 100µl of test strain inoculums were inoculated into the medium contained in conical flasks and incubated on rotary shaker (Gallen Kamp, Germany) (30°C for 96 h at 100 rpm). Growth of the five isolates was monitored spectrophotometrically by measuring the optical density at 600 nm.

2.3 Screening of the Isolates for Enzymes

2.3.1 Determination of Amylolytic Activity

The methodology used was described by Hankin and Anagnostakis (1975). Isolates were inoculated in modified nutrient agar with 0.2% of soluble starch (Sigma Aldrich, Germany). After incubation in a flat bed incubator (Carbolite 301 Controller, Jencons, United Kingdom) (at optimum temperatures for each isolate for 96 h), the cultures were treated under iodine vapours, which allowed the visualization of clear halos around the colonies.

2.3.2 Determination of the Esterasic Activity

The media used was as described by Sierra (1975), containing (g/l): peptone 10.0, NaCl, $CaCl_2$ $2H_2O$ 0.1, agar 18.0. To the sterilized culture media, previously sterilized Tween 80 was added in a final concentration of 1% (v/v). The medium was inoculated with the isolate and incubated (at optimum temperatures for each isolate for 96 h). An opaque zone of crystals was recorded as positive reaction for hydrolysis of Tween 80 (Sands, 1990).

2.3.3 Determination of the Lipolytic Activity

The media used was as described by Sierra (1975), containing (g/l): peptone 10.0, NaCl, $CaCl_2$ $2H_2O$ 0.1, agar 18.0. To the sterilized culture media, previously sterilized Tween 20 was added in a final concentration of 1% (v/v). The medium was inoculated with the isolates and the presence of hydrolytic halos observed after four days of incubation.

2.3.4 Determination of the Proteolytic Activity

To determine protease activity, a media containing nutrient broth 8 g/l, sugars 1 g/l and agar 18 g/l was used according to (Vieira, 1999). After autoclaving, 15 ml of skimmed milk separately autoclaved was added before cooling and mixed well. 20 ml of media was poured in Petri-dishes and the isolates inoculated. After incubation in a flat bed incubator (Carbolite 301 Controller, Jencons, United Kingdom) (at optimum temperatures for each isolate for 48 h), casein hydrolysis was indicated by the presence of clear halos around the colonies.

2.4 Determination of the Enzymatic Index

The isolates were grown in modified differential broth media for 24 h. After that, aliquots of 100µl for each of the isolates broth were inoculated on the specific culture media for each enzyme to be investigated. The cultures were incubated in a flat bed incubator (Carbolite 301 Controller, Jencons,

United Kingdom) (at optimum temperatures for each isolate for 96 h). The enzymatic index (EI) was expressed by the relationship between the average diameters of the degradation halo over time (24, 48, 72 and 96 h) according to (Hankin *et al.,* 1971).

2.5 Degradation Assay of the Crude Extra-Cellular Proteins on Substrates

2.5.1 Starch

Actinobacteria isolates were cultivated in modified differential broth medium containing 0.3% soluble starch. The cultures (100mL in 500ml flasks) were incubated in an orbital shaker (at isolate optimum temperatures for 144 h at 100rpm). Crude extra-cellular proteins were extracted from the supernatant after centrifugation (Refrigerated centrifuge, H-2000, Japan) of the culture broth (10,000 × g, 20 min, 4 °C). 40 g of soluble starch was added into 500ml culture supernatant and the suspension stirred gently at 4 °C.

After 30 min, the suspensions were centrifuged (Refrigerated centrifuge, H-2000, Japan) (10,000 × *g* for 10 min), and the precipitated starch washed twice with 500ml of 20mM acetic acid-potassium acetate buffer at pH 5.5. The adsorbed enzymes were eluted from starch by shaking in 250 ml of 20 mm sodium borate buffer (pH 6.8) (40 °C for 2 h) and the released enzyme solutions was transferred in to a dialysis tubing and dialyzed overnight. The dialyzed enzyme solutions were used as the crude extra-cellular proteins for amylase activities. Paper disc (Whatman® qualitative filter paper, Grade 1, Aldrich chemical co. ltd., United States of America) were prepared using a paper punch and impregnated with the prepared enzyme solutions. This was achieved through soaking of the paper discs in the enzyme solution and thereafter draining the excess solution for 10 s. This was followed by placing the impregnated paper discs in Petri-dishes containing nutrient agar supplemented with 0.2% soluble starch (g l^{-1}). After incubation in a flat bed incubator (Carbolite 301 Controller, Jencons, United Kingdom) (27.5°C, 30°C and 32.5°C for 72 h), Petri-dishes were flooded with an iodine solution which allowed visualization of clear halos around the colonies (Hankin and Anagnostakis, 1975). Halo diameters were measured and data recorded.

2.5.2 Tween 20

Aliquots of Actinobacteria (100µl) were inoculated into 100ml portions of sterile 10% reconstituted skim milk (Kumura *et al*., 1991) and incubated in a flat bed incubator (Carbolite 301 Controller, Jencons, United Kingdom) (27.5°C, 30°C and 32.5°C for 72 h), followed by another incubation (6°C for 72 h). These portions were centrifuged (Refrigerated centrifuge, H-2000, Japan) (20,000 x *g* at 4°C for 30 min). The supernatants were filtered using 0.45-µm cellulose acetate filter units (Toyo Roshi Kaisha, Ltd., Japan). The filtrates were used as the crude extra-cellular proteins for lipase activity experiment. Paper discs were prepared, impregnated with the filtrates and placed in Petri-dishes containing media described by Sierra (1975), supplemented with 1% (v/v) Tween 20. Zones of crystals around the discs were observed, measured and data recorded after incubation (27.5°C, 30°C and 32.5°C for 72h).

2.5.3 Tween 80

Preparation of crude extra-cellular proteins was done similarly to the one of lipases as stated above. However, impregnated paper discs were placed in Petri-dishes containing media described by Sierra (1975), supplemented with 1% (v/v) Tween 80. Zones of crystals around the discs were observed, measured and data recorded after incubation at (27.5°C, 30°C and 32.5°C for 72 h).

2.5.4 Skimmed Milk

Actinobacteria isolates were grown in 100 ml of differential broth medium supplemented with 1.5 ml skimmed milk in 250 ml shake flasks in an orbital shaker (Gallen Kamp, Germany) (200 rpm at 27.5 °C, 30

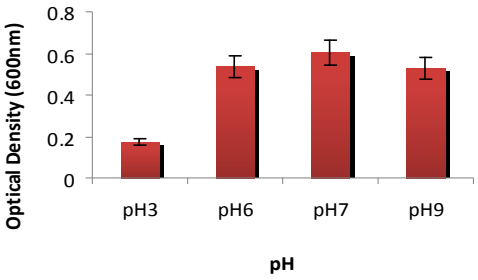
°C and 32.5 °C). Cells were harvested through centrifugation after 9 days of growth (2500 ×***g*** for 30 min). The supernatant fluid was passed over a 0·22 mm filter (Millipore), concentrated (against polyethylene glycol 4000), and dialyzed overnight at 4 °C against 0·01 mmol l^{-1} Tris-HCl, pH 7·5, containing 5 mmol l^{-1} $CaCl_2$ (Tris-$CaCl_2$ buffer). Dialyzed supernatants were used as the extra-cellular proteins. Paper discs were impregnated with the dialyzed supernatants and placed in Petri-dishes containing media described by Vieira (1999), supplemented with skimmed milk. After incubation (27.5 °C, 30 °C and 32.5 °C for 48 h), clear zones of hydrolysis were observed, measured using a ruler and data recorded.

3.0 Results

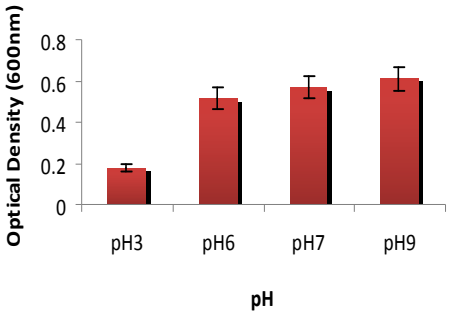
3.1 Physiochemical Characterization of Isolates

3.1.1 pH tolerance by the Isolates

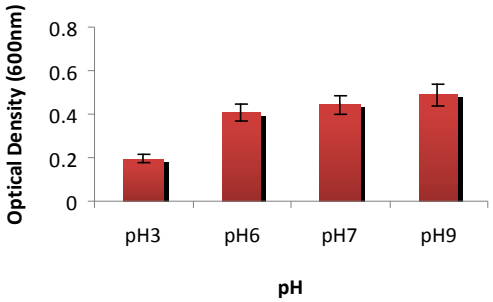
All the isolates were able to grow at acidic, neutral and alkaline pH conditions. However, the different pH conditions yielded different growth levels for the various isolates. pH 7 recorded highest growth of isolate Chy 4-10 with an optical density (OD600 = 0.604nm). Lowest growth of the isolate was recorded at pH 3 (OD600 = 0.173nm) (Figure 1a). Increased growth of isolate Chy 15-10 was recorded at pH 9 (OD600= 0.610nm) whereas minimal growth was at pH 3 (OD600 = 0.178nm) (Figure 1b). For isolate Chy 15-5, pH 9 (OD600 = 0.591nm) recorded highest growth of the isolate followed by pH 7 (OD600 = 0.549nm). Minimal growth of the isolate was recorded at pH 3 (OD600 = 0.205nm) (Figure 1c). For isolate Chy 2-3, increased growth of the isolate was recorded at pH 9 (OD600 = 0.489nm) whereas pH 3 had the lowest growth with an optical density (OD600 = 0.193nm) (Figure 1d). Lastly, highest growth of isolate Ruj 7-1was recorded at pH 6 (OD600 = 0.619nm) whereas minimal growth was at pH 3 (OD600 = 0.215nm) (Figure 1e)



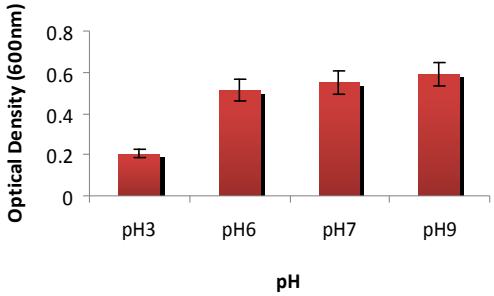
1a: Chy 4-10



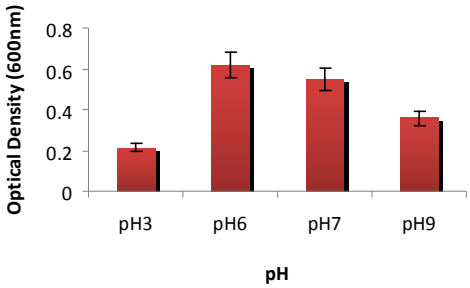
1b: Chy 15-10



1c: Chy 15-5



1d: Chy 2-3

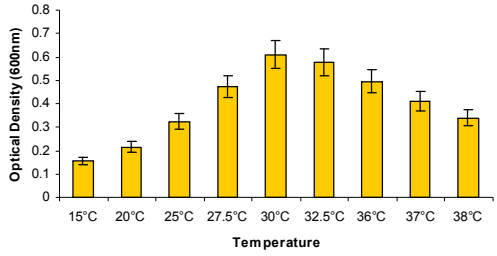


1e: Ruj 7-1

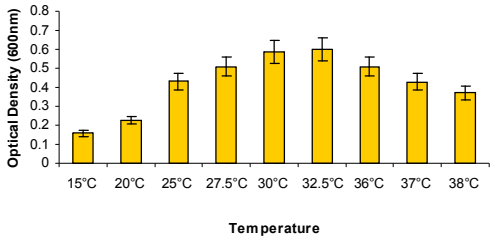
Figure 1a, b, c, d and e: Effect of pH on growth of the isolates

3.1.2 Effect of Temperature on Growth of the Isolates

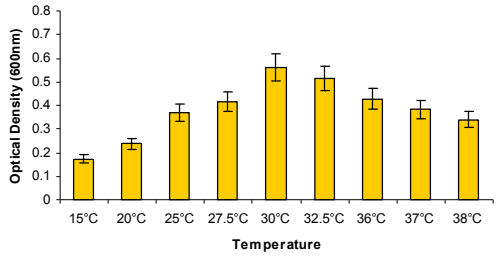
In all the isolates investigated, there was a linear increase of growth at temperature range 15 °C to 32.5 °C. With further increases in temperature, growth of the isolates was either plateau or with a linear decrease. The optimal growth temperature had the highest OD at 600nm. The optimum growth temperature for isolate Chy 4-10 was 30 °C (OD600=0.610nm). Beyond 30 °C, there was a decline in growth of the isolate (Figure 2a). For isolate CHY 15-10, 32.5 °C (OD600=0.602nm) was the optimum temperature for growth of the isolate (Figure 2b) whereas 30 °C (OD600=0.562nm) was the optimum temperature for growth of isolate Chy 15-5 (Figure 2c). For isolate Chy 2-3, the optimum temperature for growth was 32.5 °C (OD600=0.518nm) (Figure 2d). Lastly, 27.5 °C was the optimum temperature for growth of isolate Ruj 7-1 as it gave the highest growth (OD600=0.653nm) when compared with other temperature regimes (Figure 2e).



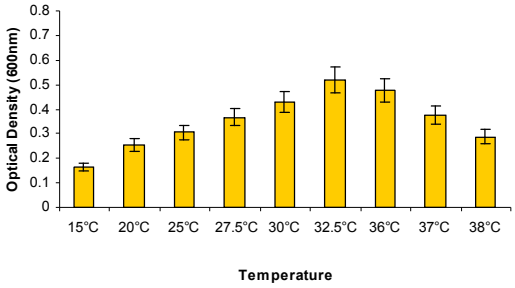
2a: Chy 4-10



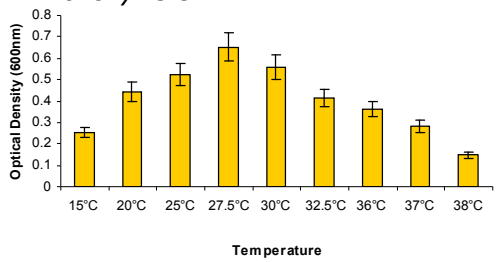
2b: Chy 15-10



2c: Chy 15-5



2d: Chy 2-3

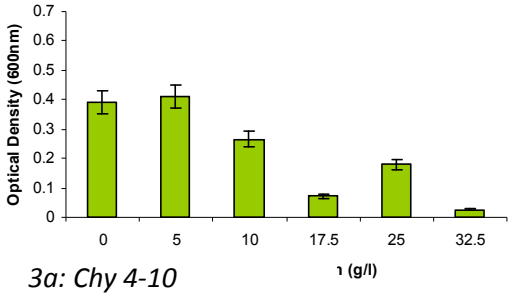


2e: Ruj 7-1

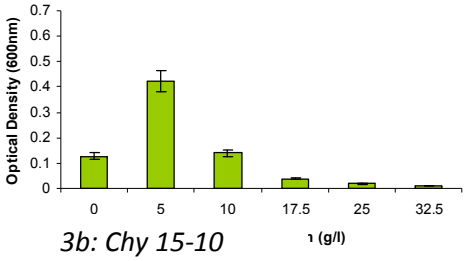
Figure 2a, b, c, d and e: Growth of isolates under different temperature regimes

3.1.3 NaCl Tolerance by the Isolates

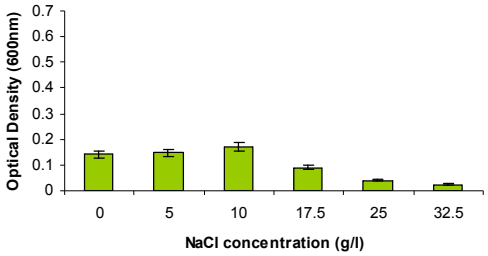
Isolates were subjected to different sodium chloride concentrations to determine the concentration for optimum growth for each isolate. All the isolates were observed to tolerate sodium chloride. Optimum growth for isolate Chy 4-10 was recorded in 5 g/l NaCl (OD600 = 0.411nm) whereas the lowest growth was recorded in 32.5 g/l NaCl (OD600 = 0.026nm) (Figure 3a). 5 g/l NaCl gave the highest growth of isolate Chy 15-10 (OD600=0.423nm). Lowest growth on the other hand was recorded in 32.5 g/l NaCl (OD600=0.010nm) concentration (Figure 3b). For isolate Chy 15-5, 10 g/l NaCl recorded highest growth (OD600=0.169nm) whereas 32.5 g/l NaCl was the concentration with the lowest growth of the isolate (OD600 = 0.023nm) (Figure 3c). For isolate Chy 2-3, optimum growth was recorded in 5 g/l NaCl (OD600 = 0.388nm) whereas lowest growth was at 32.5 g/l NaCl (OD600=0.009nm) concentration (Figure 3d). And lastly, optimum growth of isolate Ruj 7-1 was recorded in 17.5 g/l NaCl (OD600 = 0.584nm) sodium chloride concentration (Figure 3e).



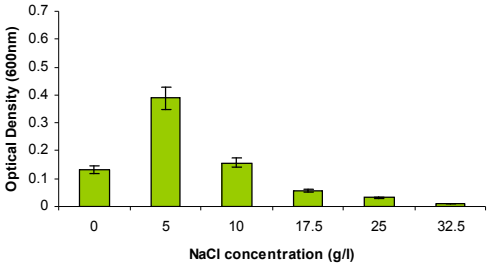
3a: Chy 4-10



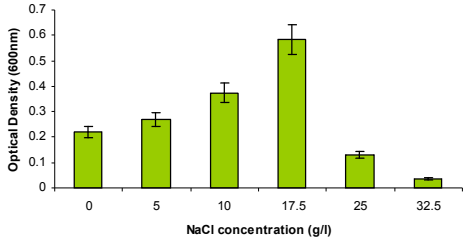
3b: Chy 15-10



3c: Chy 15-5



3d: Chy 2-3



3e: Ruj 7-1

Figure 3a, b, c, d and e: Growth of isolates under different sodium chloride concentrations

3.2 Enzymatic Activity

All the studied isolates hydrolyzed lipids, skim milk and starch apart from isolate CHY4-10 that did not hydrolyze Tween 80 (Table 1).

3.3 Enzymatic Index

On amylase-like activity, isolate Chy 4-10 expressed the highest EI (5.2±0.354) followed by isolate Ruj 7-1 with an EI of (4.4±0.354). Low EI was expressed by isolate Chy 2-3 with an EI of (3.4 ±0.354) (Table 2). EI on esterase-like activity for isolate Ruj 7-1 (5.3±0.652) was the highest followed by isolate Chy 15-5 (3.8±0.652). Isolate Chy 4-10 did not express EI on esterase-like activity (Table 2). EI on lipase-like activity for isolates Ruj 7-1 (4.2±0.548) and Chy 15-5 (4.1±0.548) were higher when compared with other isolates respectively (Table 2). Low EI on lipase-like activity was expressed in isolate Chy 2-3 (3.0±0.548) (Table 2). Isolate Chy 4-10 expressed the highest EI in terms of protease-like activity (7.3±0.707) compared to other isolates (Table 2).

3.4 Activity of the Crude Extra-Cellular Proteins on Starch, Tween 20, Tween 80 and Skimmed Milk

Enzymatic activities of crude extra-cellular proteins from the isolates were determined using various substrates. Amylase-like activity was recorded highest in isolate CHY 4-10 (27.33±0.63) and lowest in CHY 2-3 (11.00±0.63). Isolates RUJ 7-1 (17.33±0.84) and CHY 4-10 (0.00±0.84) presented highest and lowest esterase-like activity respectively whereas isolate RUJ 7-1 (23.00±0.98) recorded the highest lipolytic activity compared to other isolates (Table 3).

Table 1: Hydrolysis of substrates by the Actinobacteria isolates

	Substrates			
Isolate	Starch	Tween20	Tween80	Skimmed milk
CHY4-10	+ve	+ve	-ve	+ve
CHY15-10	+ve	+ve	+ve	+ve
CHY15-5	+ve	+ve	+ve	+ve
CHY2-3	+ve	+ve	+ve	+ve
RUJ7-1	+ve	+ve	+ve	+ve

T*able 2: Enzymatic index of the isolates on the various substrates*

Isolate	Enzymatic Index			
	Amylase (starch)	Esterase (T80)	Lipase (T20)	Protease (skim milk)
CHY 4-10	5.2 ±0.354^{a}	0.0±0.00^{d}	3.5±0.548^{bc}	7.3±0.707^{a}
CHY 15-10	4.0±0.354^{c}	3.1±0.652^{bc}	3.5±0.548^{bc}	4.4±0.707^{b}
CHY 15-5	3.7±0.354^{cd}	3.8±0.652^{b}	4.1±0.548^{ab}	4.8±0.707^{b}
CHY 2-3	3.4±0.354^{d}	2.2±0.652^{c}	3.0±0.548^{c}	2.9±0.707^{c}
RUJ 7-1	4.4±0.354^{b}	5.3±0.652^{a}	4.2±0.548^{a}	4.8±0.707^{b}

*The enzymatic index represents the halo diameter of degradation/diameter of colony in cm.
*Averages followed by the same letter don't differ among themselves (test *t* of Student, $p < 0.05$).

Table 3: Enzymatic activities of crude extra-cellular proteins

	Enzymatic activities (Diameter in mm + SE)			
Isolate	Amylase	Esterase	Lipase	Protease
CHY4-10	27.33±0.63[a]	0.00±0.84[d]	17.33±0.98[b]	21.33±0.837[a]
CHY15-10	21.67±0.63[c]	11.33±0.84[b]	13.67±0.98[c]	17.67±0.837[b]
CHY15-5	20.67±0.63[c]	16.33±0.84[a]	19.00±0.98[b]	15.33±0.837[c]
CHY2-3	11.00±0.63[d]	8.33±0.84[c]	10.33±0.98[d]	14.33±0.837[d]
RUJ7-1	24.00±0.63[b]	17.33±0.84[a]	23.00±0.98[a]	20.33±0.837[a]

* Mean values with the same letter are not significantly different at 95% confidence level (t- test).

4.0 Discussion

Physiochemical studies were carried out since most enzymes applied for industrial purposes have limitations, in exhibiting low activity and low stability at wide range of pH and temperature and secondly 30 - 40 % of production cost of industrial enzymes is estimated to be accounting for the cost of growth medium. As the composition of culture medium strongly influences enzyme production (Giarrhizzo *et al*., 2007). The study was therefore to optimize cultural conditions in order to achieve higher enzyme activities. Physiochemical characterization of the isolates Chy 4-10, Chy 15-10, Chy 15-5 and Chy 2-3 on pH showed optimal growth of the isolates at pH range of 6 - 9. These results were in accordance to Gava (1998) who reported that majority of Actinomycetes isolated from rhizosphere and non-rhizosphere soil grows at a pH range varying from 6.5 to 8.0. In addition, the wide pH range is an advantage when it comes to production of enzymes adapted to alkaline conditions in order to have good enzymatic stability. Isolate Ruj 7-1 yielded good growth, characterized by abundant mycelium, in culture media with pH 6.0 suggesting its tolerance to acidic condition. This isolate would therefore be useful in production of acid tolerance enzymes. The optimum pH level allows for optimal metabolic reactions characterized by enzymes hence the increase in growth of microorganisms (Moreira & Siqueira, 2002). Isolates CHY4-10, CHY15-10, CHY15-5, CHY2-3 and RUJ7-1 showed optimum growth at 30 °C, 32.5 °C, 30 °C, 32.5 °C and 27.5 °C respectively. Minimal growth was recorded below 27.5 °C and above 32.5 °C. Isolates Chy 15-10 and Chy 2-3 had a wider temperature range (15 °C – 32.5 °C) hence they would produce enzymes that are more stable when temperatures exceed 27.5 °C. These results also confirmed that isolates Chy 4-10, Chy 15-10, Chy 15-5 and Chy 2-3 originated from a relatively warmer ecosystem than isolate Ruj 7-1 (27.5 °C). Therefore, for isolation of enzymes from these isolates, temperature during fermentation would be different. According to Goodfellow et al. (1990), bacterial growth rates increase with temperature up to the optimum temperature, at which the growth rate is maximal. Enzymatic processes are thought to limit further increases in growth rates at temperatures above the optimum temperature.

Growth of the isolates in culture medium with varying NaCl levels (0 g/l to 32.5 g/l) confirmed tolerance to saline conditions. All the isolates recorded growth in absence of sodium chloride but isolate Chy 4-10, Chy 15-10 and Chy 2-3 indicated an increase in growth at 5 g/l sodium chloride concentration which was similar to that of *Nocardiopsis kunsanensis* sp. nov., a moderately halophilic actinomycete (Chun *et al.,* 2000). Isolate Chy 15-5 and Ruj 7-1 grew optimally at higher NaCl concentrations (10 g/l and 17.5 g/l) respectively meaning they were more tolerant and also required higher NaCl concentrations for them to grow. In terms of enzyme stability, isolate Ruj 7-1 would likely produce enzymes that are more stable to a wide range of NaCl concentrations compared to the other isolates.

Streptomyces are an important source of enzymes and bioactive products (Bull *et al*., 1992). Most produce secondary metabolites that have antibacterial, anti-fungal, anti-tumor or antiprotozoal activities making them a target for isolation in large-scale screening programs in industries.

Growth of the isolates on solid media containing the various substrates as the only carbon sources demonstrated that these isolates secreted enzymes as per the studied substrate. All the studied isolates hydrolyzed lipids, skim milk and starch. Tween 80 was hydrolyzed by all the other isolates apart from isolate CHY 4-10. Isolate Chy 4-10 recorded highest degradation of starch (27.33 ± 0.63^{a}) and skim milk (21.33 ± 0.837^{a}) whereas Ruj 7-1 had the highest degradation of Tween 20 (23.00 ± 0.98^{a}) and Tween 80 (17.33 ± 0.84^{a}). Hydrolysis of the various substrates was an indication of the ability in the various isolates to produce lipases, proteases, amylases and esterases that are industrially important enzymes. These enzymes also play an important role in promotion of plant growth and biological control of plant diseases (Moreira and Siqueira, 2002). Starch is the most important organic reserve compound of plants and among the good starch decomposers are the Actinomycetes which produce organic acids, CO_2, and dextrin during the decomposition process (Moreira and Siqueira, 2002).

Enzymatic index (EI) was determined by directly correlating the diameters of the halo of degradation and that of colony (Lin *et al.,* 1991). The EI is a practical tool that facilitates and speeds the selection and the comparison of the enzymatic production of different isolates. Fungaro and Maccheroni (2002) suggested that EI larger than 1.0 were indicative of excretion of enzymes. It was observed that all the isolates possessed at least one enzymatic activity tested (Table 3).

The amylolytic activity was observed in all isolates with Chy 4-10 showing the highest EI of (5.2 ± 0.354). Isolate Chy 4-10 had a higher EI when compared with *Actinomyces pyogenes* that had an EI of 1.2cm in a previous study carried out by Aysha *et al*., (2006).

Among the producers of esterases, four isolates showed positive results apart from isolate Chy 4-10. Isolate Ruj 7-1 had the highest EI of (5.3 ± 0.652). This was an indication of the potential this isolate had as producer of these enzymes. In this experiment, all the isolates produced extracellular lipases although EI differed among the isolates due to the differences in levels of lipase production. Isolate Ruj 7-1 gave the highest EI in lipase activity (4.2 ± 0.548) followed by isolate Chy 15-5 (4.1 ± 0.548). This is a positive indication of the potential these isolates have in terms of lipase production.

All the isolates produced proteases though the best proteolytic production was observed in isolate Chy 4-10 (7.3 ± 0.707). These results form a platform for further studies and also revealed alternative sources of amylase, lipase, esterase and protease enzymes with applicable biotechnological potential in different areas such as in the nutrition, detergent, paper, pharmaceutical, textile and leather industries.

5.0 Conclusion and Recommendation

This study showed that all the isolates were Gram positive and they grew optimally between 27.5°C - 32.5°C, pH ≥ 6 and at 5 - 32.5g/l NaCl concentration. The isolates also hydrolyzed Tween 20, Tween 80, skim milk, starch; indicating that they are an important source of lipase, esterase, protease and amylase enzymes. However, further purification procedures of the proteins secreted by these isolates through various chromatographic techniques are necessary in order to characterize them and determine their activity.

Acknowledgement
This work was financially supported by Jomo Kenyatta University of Agriculture and Technology RPE-division through Prof. Hamadi Iddi Boga. I am extremely indebted to them for the research funds without which it would not have been possible to do this work.

References

Abramic, M., Lescic, I., Korica, T., Vitale, L., Saenger, W. and Pigac, J. (1999). Purification and properties of extracellular lipase from *Streptomyces rimosus*. *Enzy Microb Technol.,* **25**, pp 522 - 529.

Aysha, .J. I. C., Edweis, .C. B. and Jose, .D.G.V. (2006). Enzymatic Activity of Endophytic Bacterial Isolates of *Jacaranda decurrens* Cham. (Carobinha-do-campo). *Braz. Archi. of Bio. and Techno.,* **49**(3) pp 353 - 359.

Berdy, J. (2005). Bioactive microbial metabolites. *J. Antibiot.* **58,** pp 1- 26.

Bergey's manual of determinative bacteriology 2000 Actinomycetales, 9th edition.

Boing, J. T. P. (1982). Enzyme production. **In**: Prescott and Dunn's Ind Microbiol. Reed, G. (Ed). Connecticut: AVI, pp. 690.

Bornscheuer, U. T. and Kazlauskas, R. J. (1999). Designing enantioselective reactions. In Hydrolases in Organic Synthesis. Weinheim: Wiley-VCH. pp 32 - 38.

Bull, A. T., Goodfellow, M. and Slater, J. H. (1992). Biodiversity as a source of innovation in biotechnology. *Annu. Rev. Microbiol*., **46,** pp 219 - 252.

Chun, J., Bae, K. S., Moon, E.Y., Jung, S. O., Lee, H. K. and Kim, S .J. (2000). *Nocardiopsis kunsanensis* sp. nov., a moderately halophilic actinomycete isolated from a saltern. *Int. J. Syst. Evol. Microbiol.,* **5,** pp 1909 - 13.

Fairbarn, D. A., Priest, F. G. and Stark, J. R. (1986). Extracellular amylase synthesis by *Streptomyces limosus*. *Enzyme Microb Technol.,* **8,** pp 89 - 92.

Falch, E. A. (1991). Industrial enzymes – developments in production and application. *Biotech Advance*, **9,** pp 643 - 658.

Fungaro, M. H. P. and Maccheroni Jr., W. (2002). Melhoramento genético para produção de enzimas aplicadas à Indústria de Alimentos. In: Melo, I. S.; Valadares-Inglis, M. C.; Nass, L. L. and Valois, A.C.C. (Eds.). *Recursos Genéticos e Melhoramento- Microrganismo*. Jaguariúna: Embrapa Meio Ambiente, pp. 426 - 453.

Gava, C. A. T. (1998). Seleção de estreptomicetos para controle biológico de *Ralstonia solanacearum* e *Erwinia carotovora*. Rio de Janeiro: Universidade Federal do Rio de Janeiro, **p** 114. dissertação (Mestrado).

Gerhartz, W. (1990). Enzymes in Industry: Production and Applications. VCH, Weinnheim, **p** 88.

Giarrhizzo, J., Bubis, J. and Taddei, A. (2007). Influence of the culture medium composition on the excreted /secreted proteases from *Streptomyces violaceoruber. World J. Microbiol Biotechnol.,* **23,** pp 553 - 558.

Goldberg, J. D. and Edwards, C. (1990). Purification and characterization of an extracellular amylase from a Thermophilic streptomycetes. *J. Appl. Bacteriol.,* **69,** pp 712 - 717.

Goodfellow, M., Stanton, L. J., Simpson, K. E. and Minnikin, D. E. (1990). Numerical and chemical classification of *Actinoplanes* and some related Actinomycetes. *J. Gen. Microbiol.,* **136,** pp 19 - 36.

Hankin, L. and Anagnostakis, S. L. (1975). The use of solid media for detection of enzyme production by fungi. *Mycologia*, **67,** pp 597 - 607.

Hankin, L., Zucker, M. and Sands, D. C. (1971). Improved solid medium for the detection and enumeration of pectolytic bacteria. *Appl of Microbiol*., **22,** pp 205 - 209.

Hendrickson, D. A. and Krenz, M. M. (1991). Reagents and stains. In *Manual of Clinical Microbiology*. Balows, A., Hausler, W. J., Herrmann Jr, K. L., Isenberg, H. D. and Shadomy H. J. (Eds). pp. 1289–1314. Washington, DC: American Society for Microbiology.

Hostinova, E. and Zelinka, J. (1978). Alpha-amylase from *Streptomyces aureofaciens* - Purification and properties. *J. Starch/Stärke.* **30,** pp 338 - 341.

Kieser, T., Bibb, M. J., Buttner, M. J. and Chater, K. F. (2000). Practical *Streptomyces* genetics. Hopwood D. A. (Ed.). John Innes Centre, Norwich, England.

Kumura, H., Mikawa, K. and Saito, Z. (1991). Influence of concomitant protease on the thermostability of lipase of psychrotrophic bacteria. *Milchwissenschaft.* **46,** pp 144 - 149.

Large, K. P., Mirjalili, N., Peacock, M. O. L., Zormpaidis, V., Walsh, M., Cavanagh, M. E., Leadlay, P. F. and Ison, A. P. (1999). Lipase activity in Streptomycetes. *Enzy Microb Technol.,* **25,** PP 569 - 575.

Marrs, B., Delagrave, S. and Murphy, D. (1999). Novel approaches for discovering industrial enzymes. *Curr Opin Microbiol,*. **2,** pp 241 - 245.

Mayfield, C. I., Williams, S. T., Ruddick, S. M. and Hatfield, H. L. (1972). Studies on the ecology of Actinomycetes in soil. IV. Observations on the form and growth of streptomycetes in soil. *Soil Biol Biochem*., **4,** pp 79 - 91.

Moon, S. H. and Parulekar, S. J. (1991). A parametric study of protease production in batch and fed batch cultures of *Bacillus firmus*. *Biotechnol Bioeng.,* **37,** pp 467 - 483.

Moreira, F.M.S. and Siqueira, J.O. (2002). Microbiologia e bioquímica do solo. Lavras: UFLA, pp 626.

Newman, D.J. and Cragg, G.M. (2007). Natural products as sources of new drugs over the last 25 years. *J.Nat. Prod.,* **70,** pp 461 - 477.

Norman, B. E. (1978). In: Microbial Polysaccharides and Polysaccharases. Berkeley, R. C. W., Ellwood, D. C. and Gooday, G. W. (Eds). **pp**. 340 - 375. Academic Press, London.

Nout, M. J. R. and Rombouts, F. M. (1990). Recent developments in Tempe research. *J. Appl. Bacteriol.,* **69,** pp 609 - 633.

Olano, C., Méndez, C. and Salas, J. A. (2009). Antitumor compounds from Actinomycetes: from gene clusters to new derivatives by combinatorial biosynthesis. *Nat. Prod Rep*., **26,** pp 628 - 660.

Phadatare, S. U., Deshpande, V. V. and Srinivasan, M. C. (1993). High activity alkaline protease from *Conidiobolus coronatus* (NCL 86.8.20): Enzyme production and compatibility with commercial detergents. *Enzyme Microb Technol.,* **15,** pp 72 - 76.

Pilnik, W. and Rombouts, F. M. (1985). Polysaccharides and food processing. *Carbohy Res*., **142,** pp 93 - 105.

Porto, A. L. F., Campos-Takaki, G. M. and Lima Filho, J. L. (1996). Effects of culture conditions on protease production by *Streptomyces clavuligerus* growing on soy bean flour medium. *Appl. Biochem. Biotech*., **60,** pp 115 - 122.

Rao, M. B., Tanksale, A. M., Ghatge, M. S. and Deshpand, V. V. (1998). Molecular and Biotechnological Aspects of Microbial Proteases. *Microbiol and Mol Biol Rev*., **62,** pp 597 - 635.

Sands, D. C. (1990). Physiological criteria-Determinative tests. *In:* Methods in Phytobacteriology. Klement, Z., Rundolph, K. and Sands, D. C. (Eds). pp. 134 - 143. Akademiai Kiado, Budapest, Hungary.

Sierra, G. A. (1957). A simple method for the detection of lypolytic activity of microorganisms and some observations on the influence of the contact between cells and fatty substracts. *Antonine van Leeuwenhoeck,* **28,** pp 15 - 22.

Sommer, P., Bormann, C. and Gotz, F. (1997). Genetic and biochemical characterization of a new extracellular lipase from *Streptomyces cinnamomeus*. *Appl Environ Microbiol*., **63,** pp 3553 - 3560.

Suganuma, T., Hiromi, K., Mizukami, K., Moori, M. and Ohnisi, T. (1980). Studies on the action pattern of an α-amylase from *Streptomyces praecox* NA-273. *J. Biochem*., **88,** pp 131.

Takaya, T., Fuwa, H., Sugimoto, Y. and Wako, K. (1979). Degradation of starch granules by alpha-amylase of *Streptomyces praecox* NA- 273. *Starch/Stärke,* **31,** pp 205 - 208.

Tesch, C., Nikoleit, K., Gnau, V., Gotz, F. and Bormann, C. (1996). Biochemical and molecular characterization of the extracellular esterase from *Streptomyces diastatochromogenes*. *J. Bacteriol*., **178,** pp 1858 - 1865.

Vieira, J. D. G. (1999). Purificação e caracterização de uma a-amilase de *Streptomyces sp*. PhD. Thesis, Universidade de São Paulo, Brazil.

Watve, M. G., Tickoo, R., Jog, M. M. and Bhole, B. D. (2001). How many antibiotics are produced by the genus *Streptomyces*? *Arch Microbiol*., **176,** pp 386 - 390.

SEASONAL CHARACTERISTICS OF AVIFAUNA IN NAIROBI METROPOLITAN LANDSCAPE

J. B. Njoroge[1] and P. K. Nda'Nganga[2]
[1]Department of Horticulture, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[2]Birdlife International, Kenya
E-mail: njbosco@hotmail.com

Abstract
The landscape structure of Nairobi city is experiencing rapid transformation as once wild and pristine spaces are converted to anthropocentric uses. In order to understand how the changing urban structure affects urban habitats, the seasonal variation in occurrence and composition of avifauna within the metropolitan landscape of Nairobi city was investigated. The relationship between bird occurrence and spatial characteristics of surrounding urban matrix was quantified. Bird survey was conducted for two consecutive seasons in the wet and dry seasons. Landscape features within the study sites were derived from remote sensing image and used to account for bird distribution. Birds were classified according to their biological families and their naturally preferred habitat. Ordination analysis was done to find underlying correlation between species occurrence and site characteristics. About 50 different families of birds were observed between the two seasons with a total of 307 different species. Families of finches, raptors, warblers and weavers, sunbirds and thrushes were the most common. Bush and scrub habitats were most naturally preferred habitat at a rate of about 31%, followed by grassland species at about 20% and forest species at about 16% rate. Unique species recorded between the seasons constituted 22% and 17% of total observed for the dry and wet seasons respectively. The first axis of principle component analysis revealed a gradient of change from forested and woody sites to savannah vegetated sites while the second axis was change from sites with agriculture patches to sites with urban patches. The occurrence and distribution of the species was highly dependant on site use and management. As the city continues to expand, landscape and urban planners must promote urban designs that will integrate habitat conservation for healthy urban space development.

Key words: Urban landscape, site characteristics, species richness, habitat type, management

1.0 Introduction

Remnant habitats in urban areas are important in providing critical ecosystem services such as storm water control, habitat for wildlife and mitigating effects of urban heat and air pollution. Most urban landscapes especially in developing countries are being transformed to a less natural state at an alarming rate creating markedly different conditions for urban wildlife and avifauna. By preserving remnants of fragmented landscapes, valuable habitats and wildlife can be preserved as proved by various studies such as that of Fiona and Ralph (2005) and John et.al., (2005). Among other vertebrates, birds provide a useful mechanism to explore urban effects and responses to different urban designs (Bibby et al., 1998). Studies have shown that the avifauna community restructures its distribution pattern and responds by either adapting to or avoiding the resultant fragments according to the landscape scale and their inherent behavioral traits (Croci, 2008). Despite tropical habitats being considered to carry high avian diversity, there is paucity of information available and thus local knowledge and study is needed to enhance management policies that mitigate disturbance and urbanization impacts on habitats and bird communities (Chace and Walsh, 2006). Information on urban processes and their impacts for the city of Nairobi need to be availed and applied within a context of urban ecological planning system to meet the goals of sustainable cities and guarantee quality urban environment and contributing to localizing the agenda 21. The specific objectives of this study were to determine bird species composition in the urban landscape of Nairobi, Kenya, to validate whether significant differences in species composition occur between sites and seasons.

2.0 Materials and Methods

2.1 Study Area and Study Approach

The study site covered the area within latitudes $1^{o}10'$ and $1^{o}25'$S and longitudes $37^{o}00'$and $36^{o}34'$E, (Figure 1). Elevation varies from about 1450 meters on the south eastern side to a high of about 2200 m in the north western side. Mean monthly rainfall varies from a low of 15 mm to a high of 212 mm. There are two temperature regimes highest in January at about 25^{o}C during the day and 12^{o}C at night and lowest in July at about 21^{o}C during the day and 11^{o}C at night. The total land area of the city and surrounding environs included in the study was about 1575km^2. The area has experienced rapid land cover / land use changes due to population pressure, urban expansion, and various economic activities especially in the past two decades.

2.1.1 Avifauna

Using existing maps of Nairobi, sampling sites were selected through a systematic sampling method of the entire study area (Figure 1). A total of 20 sites, measuring about 4 km^2 each and representing different land use / land cover types of the landscape were surveyed for presence of birds. Bird identification and counting was done using point count technique as described by (Bibby *et. al*., 1998). Bird sampling was done after sunrise to capture the period when bird activity was high. All birds observed or heard within 50 m radius of the census station were recorded. Birds' censuses were conducted in the wet cold season of July, 2007, dry season of February, 2008 and repeated in 2009.

2.1.2 Environmental Data

A satellite image was used to develop a map of land cover types representative of the study area. In this case, Land sat TM image of year 2000 was used. A geographical positioning system (GPS) was used to obtain co-ordinates for training sites in order to apply a pixel-based supervised classification of the Land sat image using ERDAS Imagine software. The land cover classes applied in the study were based on the AFRICOVER land cover classification system. The descriptions of the land cover types were modified to suit the characteristics and land cover diversity of the study area. Overall image classification resulted into seven thematic land cover classes namely; water, agriculture, urban, forest and woods, savannah

vegetation, riverine and barren surface. Land cover types constituted the environmental data for the sample sites that was derived through feature extraction of the classified satellite image. A centrally positioned point of each sample site relating to the bird census points, was placed on the classified image of the study area and was expanded to radius of 500 m using buffer command on ArcGIS 9.0 (ESRI) to give an output feature class image of each sample site. The area values for each of the land cover variable was computed and expressed as proportion of the total area of the 500 m radius polygon.

2.2 Data Analysis

The principle component analysis method was applied to identify environmental variables that best explained the variation in sample sites and hence influence pattern of bird distribution. Cluster analysis was then conducted in order to group similar sites on the PCA ordination plane. Birds were classified according to their biological families as presented by various illustrated checklists such as by Zimmerman et., al, 1999, Ber Van Perlo, 1995 and Stevenson, 2002. The total abundance of all bird species observed in a given site and the number of different species observed was computed. Abundance was given as total count per site and species richness as the total number of different species observed. Bird species diversity for each censused site was computed using the Shannon-Weiver (1949) information theory formula. In order to determine whether or not the values for above variables differed between seasons and groups the Kruskal-Wallis one-way ANOVA test was applied. It tests the null hypothesis that multiple independent samples come from the same population using the mean ranks of the variables. Further, birds were categorized according to their naturally preferred habitat as described by existing check lists of the birds of Nairobi such as by Harvey, 1997 and Britton, 1980. Only the predominant preferred habitat was considered in this categorization. In this case seven categories were identified. Occurrence of birds with respect to status of residence was also used to account on birds' distribution. The predominant status that were considered were; resident, for species that can be seen in any month and probably breeds in or near Nairobi area; northern migrant, for species that migrate from the north such as Europe and western Asia as winter visitor or passage migrant (palaearctic); and African visitor for migrants from other parts of Africa (afrotropical). The Mann-Whitney U test was applied to test for significant differences between the cluster groups and between seasons

3.0 Results and Discussions

3.1 Site Characteristics and Bird Occurrence

Principle component analysis of the sites showed that the first three axes accounted for over 80% of the total variation (Table 1). The first axis represented a change from savannah vegetation cover to sites comprised of water patches. The second component showed a change from sites comprised of forest and wood cover type to sites comprised of agricultural, barren and urban patches (Figure 2). Cluster analysis of the sites conducted based on hierarchical cluster analysis resulted into four cluster groups. The cluster group membership and the mean land cover proportion of each land cover type is shown in Table 2. The sites were grouped as follows, cluster I sites, 1, 2, 4, 5, 6, 11, 12, 13 and 20; cluster II sites, 3, 9, 10 and 19; cluster III sites, 7, 8, 14, 15 and 16 and cluster IV sites 17 and 18. Cluster I is distinguished by low proportion of all other land cover types except savannah vegetation which was dominant at above 94%. Cluster II sites differ from other clusters by lack of water type of land cover and highest proportion of urban type of land cover. Cluster III features the highest proportion of forest and woods while cluster IV is distinguished by having the highest proportion of agriculture type of land cover.

In total, 290 birds were observed in the wet and 307 in the dry seasons, respectively. They represented about 55 different bird families. The families of raptors and warblers were markedly more common in

the dry than the wet season although two family groups of avocets and stilts, and Gulls and Terns were absent in the dry season while all the family groups were represented in the wet season. Overall, bird abundance, species richness and diversity were 1023, 82 and 3.5 for the wet season and 885, 88 and 3.7 for the dry season, respectively. According to Mann-Whitney U test for difference between seasons, abundance was significantly higher in the wet than in the dry season. However, there was significantly high species richness and diversity in the dry than in the wet season. This could be attributed to the appearance of palearctic migrant species which appear this time of the year when winter sets in the northern hemisphere prompting certain bird species to migrate south towards the equator.

With cluster grouping, bird abundance was high in the wet season than in the dry season in all clusters except cluster IV with the highest land cover for agriculture (Table 2). Clusters with high proportion of savannah vegetation recorded high abundance of birds. In contrast, species richness was highest in the dry season in all clusters as compared to the wet season. Similarly, the highest species diversity occurred in the dry season especially in the clusters dominated with forest and agriculture. Kruskal-Wallis H test for differences between clusters was conducted for the three variables of bird abundance, species richness, and species diversity, by type of cluster group for the wet and dry seasons. The asymptotic significance estimates the probability of obtaining a chi-square statistic greater than or equal to the one displayed, if there truly are no differences between the group ranks. Except for species richness for the dry season, the asymptotic significance was much lower than the calculated chi-square statistic in all cases implying that the ratings for abundance, species richness and species diversity, differed by cluster irrespective of the season.

Seasonal species-habitat distribution pattern

With respect to status of movement, more than 80% and 78% of the birds were resident birds in the wet and dry season, respectively. The most significant difference between seasons was in palaearctic migrant species, the highest rate being recorded in the dry than in the wet season (Table 3). Clusters I and II recorded the highest percentage of migrant species while clusters III and IV had the lowest rate of palaearctic migrant species in the wet season. This indicates that many migrant birds do take refuge in sites within Nairobi landscape either on their migratory route or as feeding points. The commonest palaearctic migrant species were Barn swallow, Pied wagtail and Common sandpiper in the wet season and Yellow wagtail , Willow warbler and Isabelline wheatear in the dry season.

On the naturally preferred habitat, species related to bush habitat were most common at rate of 30.8% and 32.6% of all recorded species for the wet and dry seasons, respectively (Figure 3). The rate of occurrence was highest in cluster I, followed by cluster II, which matched the land cover composition of sites in these clusters marked by high savannah type of land cover which comprises dry bushed grassland with acacia shrubs, riverside shrubs, garden shrubs and hedges (Table 3). Majority of the sites in cluster I are located on the southern and south eastern parts of Nairobi that have natural savannah grasslands and acacia shrubs especially within the Nairobi national park. Three of the sites in cluster II are in urban core area and are rapidly urbanizing and comprise of ornamental garden shrubs and hedges with scattered patches of the original savannah type of vegetation. Shrub species with high frequency included, Northern pied babbler, Rattling cisticola, Rufous sparrow, Singing cisticola and White-browed sparrow-weaver in addition to Diederic cuckoo and Yellow-rumped seedeater that were observed only in the dry season. Grassland birds were the next most common with no significant differences between the seasons (Fig. 3). Clusters I and II recorded the highest rate, while cluster IV had the lowest rate. Frequent grassland species recorded included, Black-headed heron, Cattle egret, Grassland pipit, Red-billed quelea and Rufous-naped lark. Species of Pin-tailed whydah, Red-collared widowbird and Yellow wagtail were common in the dry season. Species with natural preference for forest and wooded areas

were the third commonest of all recorded birds. Overall, more forest birds were recorded in the wet than in the dry season. Cluster III recorded the highest rate of forest related birds and unlike in the other clusters, the proportion recorded was higher in the wet than in the dry season (Table 3). Forest related species with highest frequency included African paradise flycatcher, Black saw-wing, Chin-spot batis, Little sparrowhawk, Olive thrush and Red-chested cuckoo. Species associated with wetlands such as swamps, streams, dams and sewerage ponds were most frequent among cluster I sites followed by sites of cluster III. They included, Common waxbill, Dark-capped yellow warbler, Grey heron, Hamerkop, Long-tailed cormorant and Malachite kingfisher. Aerial species that are usually seen in flight where they also obtain most of their food recorded high rates among sites of cluster I, followed by cluster II and then cluster III. The predominant aerial species were, Lesser striped swallow, Plain martin, Red-rumped swallow, Rock martin and Barn swallow. Aerial species such as Eurasian bee-eater. and Sand martin were recorded only in the dry season. Species for structures such as those that prefer buildings commonly in urban areas were lowest in proportion overall. Their occurrence was highest in cluster I and cluster II and least in cluster IV, (Table 3) and included House sparrow, Little swift and Speckled pegion. The final habitat category is diverse, for species that occur regularly and are frequently observed. All clusters had equally high proportion of diverse species such as Common fiscal, Red-billed fire finch, Baglafecht weaver, Common bulbul, Pied crow, Sacred ibis and Black kite.

Evaluation for significant differences in habitat's species distribution between the two seasons along the different clusters was done using the Mann-Whitney test. Low difference between seasons was observed when sites were evaluated together without clustering. However the difference in site composition was apparent when bird distribution between seasons was analyzed among more similar site clusters. Thus cluster II distinguished by high proportion of urban area and bushed land and cluster IV distinguished by high proportion of agricultural area showed higher significant difference in species composition between the two seasons as compared to clusters I and III. Palearctic species increased in the dry season and most are aerial species, grassland and bush utilizing species. Thus grassland, bush land and agricultural patches play a significant role of habouring migratory bird species in the dry season.

4.0 Conclusion and Recommendation

The analysis shows that diversity of landscape characteristics influence composition and distribution of avifauna in the study area with marked seasonal differences. Although high species abundance was recorded in the wet than in the dry season, species richness and diversity were higher in the dry than in the wet season. Distribution of resident species was low in sites dominated by agricultural activities. All palaearctic migrant species in sites with agricultural patches occurred only in the dry season showing the selective nature of the birds for these areas possible due to the high availability of grains and presence insect pests. Shannon species diversity was high in the cluster of sites with agriculture and forest patches than in cluster sites with urban and savannah patches especially in the dry season. Thus these sites are important for seasonal birds and high biodiversity. Vegetated sites and riparian sites have been observed in various studies to enhance occurrence of rare bird species in urban areas for example (Koide et. al., 2004) and in the urban periphery (Sandstrom et. al., 2006). While the abundance of bird species in the human inhabited areas was high, cluster II, variability as shown by species richness was low. Site specific differences influenced the type and level of occurrence of different bird species. Urban planners and managers in Nairobi can enhance seasonal bird diversity by integrating original natural land cover types into open space plans. This will require both local and regional based approach to land use planning informed by landscape metrics of the environment.

References

Ber Van, P. (1995). Birds of Eastern Africa. Harper Collins Publishers, London.

Bibby, C., Martin, J. and Stuart, M. (1998). Expedition Field Techniques. Bird Surveys. Expedition Advisory Center, Royal Geographical Society, London, U.K.

Borghesio, L. and Paola L. (2004). Seasonal foraging ecology in a forest avifauna of northern Kenya. Ostrich, *Journal of Tropical Ecology,* **20**, pp145–155.

Britton, P. L., Eds. (1980). Birds of East Africa, their status and distribution. Nairobi: East African Natural History Society.

Brooks, Daniel, M., Lucio Pando-Vasquez and Angel Ocmin-Petit. (2005). The relationship between environmental stability and avian population changes in amazonia. *Ornitologia Neotropical,* **16**, pp 289–296.

Croci S., Alain, B. and Philippe, C. (2008). Does urbanization filter birds on the basis of their biological traits? The Condor, *International Journal of Avian Biology*, **110**(2), pp 223–240.

Fiona, Y. and Ralph Mac, N. (2005). The avifaunas of some fragmented, periurban, coastal woodlands in south-eastern Australia. *Journal of Landscape and Urban Planning,* **72**(4), pp 265-351.

Harvey, B., (1997). Annotated Checklist of the Birds of Nairobi including Nairobi National Park. The British Council, The Regal Press, Nairobi, Kenya.

John, G. W., Mark, J. A., James, A. F. and Grant, C. P.(2005). Non-uniform bird assemblages in urban environments: the influence of streetscape vegetation. *Journal of Landscape and Urban Planning,* **71**(2), pp 123-135.

Koide M., Kato K. and Watanabe S. (2004). *Journal of the Japanese Institute of Landscape Architecture,* **67**(5), pp 573-576.

Sandstromm, U. G., Angelstam, P. and Mikusinski, G. (2006). Ecological diversity of birds in relation to the structure of urban green space. *Journal of Landscape and Urban Planning,* **77**, Issue 1-2, 15 pp, 39-53.

Shannon, C. E. and Warren W. (1949). The mathematical theory of communications. Urbana: University of Illinois Press.

Terry Stevenson and John Fanshawe. (2002). Field Guide to the Birds of East Africa. T. and A.D. Poyser Publishers, London.

Zimmerman, D. A., Donald A. T., David J. P., Ian W. and H. Douglas Pratt. (1999). Birds of Kenya and Northern Tanzania. Princeton University Press, USA.

Tables

Table 1: Principle components and eigenvectors of the land cover types

	Principal component		
	1	2	3
Eigen value	3.19	1.36	1.04
Percent of variance	45.63	19.40	14.90
Cumulative variance (%)	45.63	65.02	79.92
Land cover types	Eigenvectors		
Water	-0.417	0.055	-0.277
Agriculture	-0.393	-0.458	-0.134
Urban	0.101	-0.460	0.709
Forest & Woods	-0.359	0.496	0.415
Savannah	0.492	0.021	-0.417
Riverine	-0.347	0.365	-0.054
Barren Land	-0.413	-0.444	-0.232

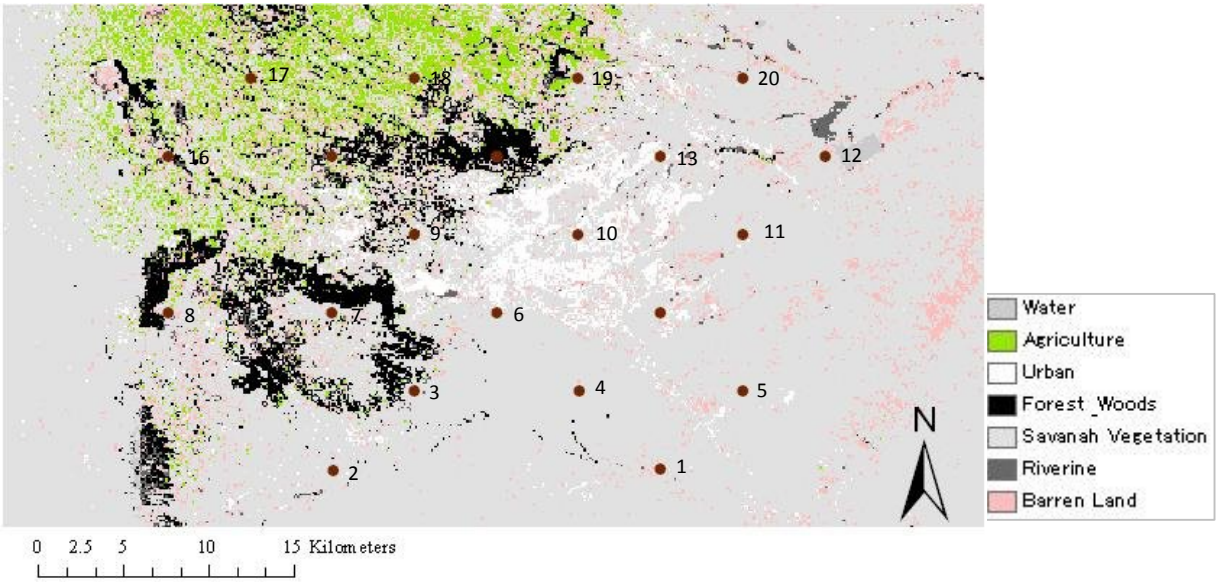
Table 2: Proportion of the land cover types and species statistic within cluster groups

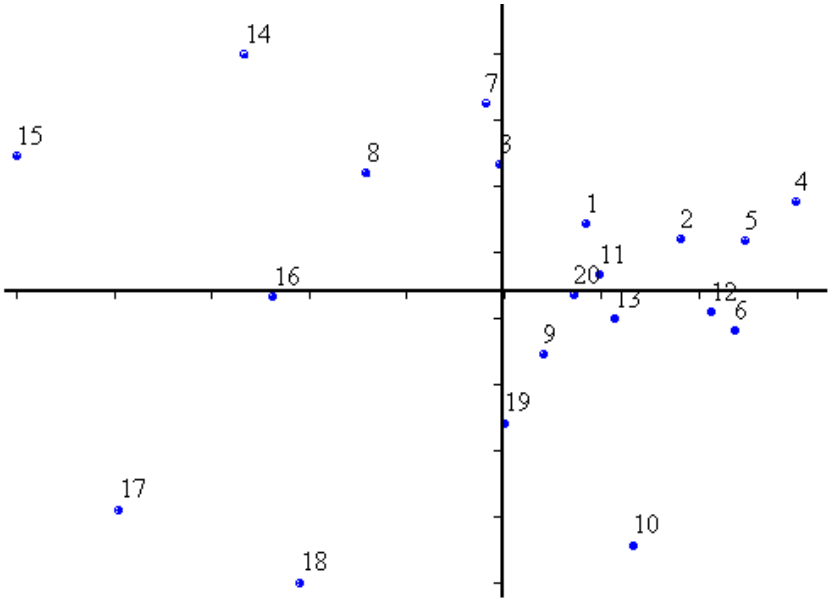
No. of sites	Cluster I (9)	Cluster II (4)	Cluster III (5)	Cluster IV (2)
Land cover type				
Water	0.07±0.2	0.00±0.00	0.53±0.74	0.83±1.17
Agriculture	0.03±0.09	2.60±3.24	5.57±5.95	*45.88±7.62*
Urban	1.09±2.09	*12.94±18.54*	0.81±0.96	0.42±0.39
Forest and Woods	0.26±0.55	4.46±4.85	*38.90±30.23*	4.35±3.92
Savannah Vegetation	*94.87±3.58*	71.66±11.91	41.23±28.35	29.80±0.23
Riverine	0.42±0.55	1.72±2.44	5.77±7.76	0.04±0.06
Barren Land	3.26±3.24	6.63±2.97	7.20±5.18	18.69±3.09
Species statistic				
abundance				
Wet	1063.1±337.9	1266.3±323.6	830.2±335.1	841.0±91.9
Dry	918.8±414.8	1002.0±225.5	703.2±242.6	953.5±82.7
richness				
Wet	83.0±22.9	84.8±43.4	86.6±11.1	69.0±14.1
Dry	89.1±29.8	92.8±53.1	88.0±10.5	83.0±8.5
diversity				
Wet	3.4±0.4	3.6±0.4	3.6±0.4	3.5±0.1
Dry	3.7±0.4	3.7±0.6	3.8±0.3	3.8±0.1

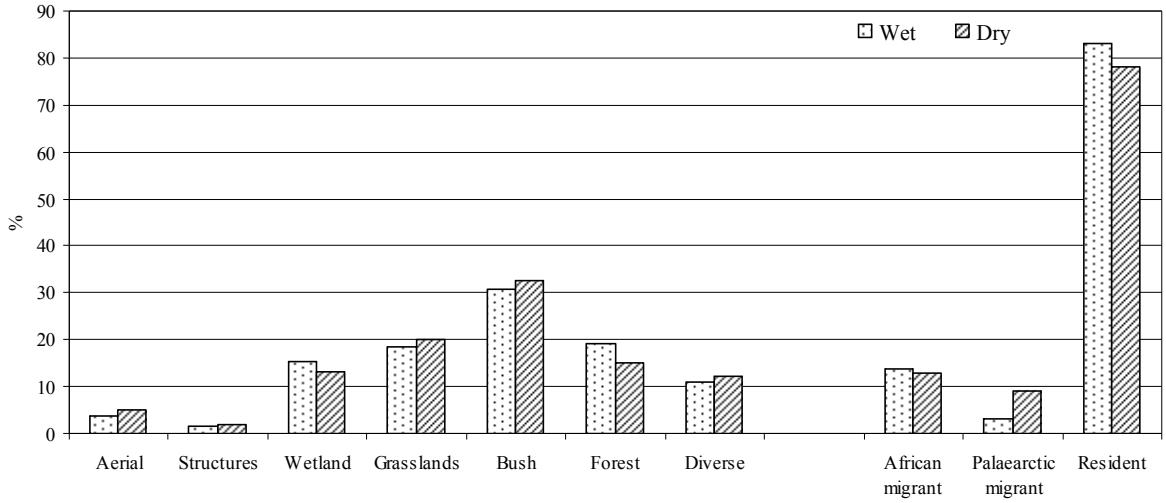
Table 3: Seasonal difference in level of occurrence of different species by cluster as a function of total recorded per category

Category	Percentage occurrence							
	Cluster I (9)		Cluster II (4)		Cluster III (5)		Cluster IV (2)	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Status								
African migrant	73.0	74.3	35.1	54.3	35.1	22.9	13.5	25.7
Palaearctic migrant	75.0	88.0	25.0	84.0	12.5	64.0	0.0	44.0
Resident	82.4	89.7	69.2	74.6	69.2	66.7	36.7	44.1
Habitat	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Aerial	100.0	92.9	60.0	78.6	70.0	71.4	40.0	50.0
Structures	100.0	100.0	100.0	100.0	75.0	80.0	50.0	40.0
Wetland	92.7	97.2	39.0	55.6	53.7	52.8	31.7	33.3
Grasslands	87.8	94.5	61.2	63.6	42.9	47.3	14.3	23.6
Bush	89.0	85.4	69.5	76.4	50.0	52.8	25.6	37.1
Forest	37.3	63.4	54.9	70.7	90.2	80.5	29.4	53.7
Diverse	96.6	100.0	93.1	97.0	93.1	87.9	82.8	81.8

Figures


17
18
19
20
16
13
12
9
10
11
8
7
6
3
4
5
2
1
N
Water
Agriculture
Urban
Forest _Woods
Savanah Vegetation
Riverine
Barren Land
0 2.5 5 10 15 Kilometers


14
7
15
8
3
4
1
2
5
11
16
20
12
13
6
9
19
17
10
18


90
80
70
60
50
40
30
20
10
0
%
Wet
Dry
Aerial
Structures
Wetland
Grasslands
Bush
Forest
Diverse
African migrant
Palaearctic migrant
Resident

MALIGNANT TUMOR DETECTION USING FINITE VOLUME TIME DOMAIN

K. O. Dinga[1], D. B.O Konditi[2] and H. Ouma[3]
[1]Department of Electrical Engineering, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[2]Faculty of Engineering, Multi-Media University College of Kenya, Nairobi, Kenya
[3]School of Engineering, University of Nairobi, Nairobi Kenya

Abstract
For a long time microwave engineers have dreamed of using non-ionizing electromagnetic waves to image the human body in order to detect cancer. Over the past several years, significant progress has been made towards making this dream a reality for breast cancer detection. In the next decade, microwave systems are likely to become viable diagnostic option for many women and men alike. More so than for any other cancers, breast tumors have electrical properties at microwave frequencies that are significantly different from those of healthy breast tissues. The breast can easily be accessed from outside, while internal organs are much less accessible. Normal breast tissue is also more translucent to microwaves than many other tissues, such as muscle or brain. Phenomenal progress in computers and numerical techniques during the past decade allows us to effectively process data acquired through measurements. This work proposes a new methodology for analyzing malignant tumors. The methodology will be based on finite volume time domain (FVTD) modeling approach. In the past finite difference time domain modeling schemes have been used to detect tumors. However, though it is simple and has wide frequency coverage, its main drawback is that it is computationally intensive. To overcome this drawback finite volume time domain (FVTD) is proposed as a suitable modeling technique for the problem.

Key words: Conformal microwave technology, finite difference time domain, malignant tumor, permittivity, conductivity, finite volume time domain

1.0 Introduction

There is considerable recent debate as to whether or not women under 50 years of age should have X-ray mammograms. This debate arises from the need to detect breast cancer in its earliest stage. Early detection leads to longest survival and greatest patient comfort. While mammography is recognized as the preferred method to detect breast cancer, it fails to detect as many as 20% of the malignant tumors. Further, it may be uncomfortable or threatening to many of the patients, especially with the public perception that repeated X-ray mammograms increase the risk of cancer. Other modalities such as ultrasound and magnetic resonance imaging (MRI) are either less effective or too costly. Pulsed confocal microwave technology can complement mammography by remedying most of the above noted deficiencies.

1.1 Physical Basis of the Method

The confocal, microwave breast cancer detection technology is based upon two fundamental properties of breast tissues at microwave frequencies. Microwaves interact with biological tissues primarily according to the tissue water content. This is a different interaction mechanism than for X-rays. The relevant physical properties contrast between malignant tumors and normal breast tissues is significantly greater for microwaves than for either X-rays or ultrasound, approaching an order of magnitude. This large dielectric contrast causes malignant tumors to have significantly greater microwave scattering cross sections than normal tissues of comparable geometry.

Microwave attenuation in normal breast tissue is less than 4 dB/cm up to 10 GHz. This may permit existing microwave equipment having standard sensitivity and dynamic range to detect tumors located up to about 5 cm beneath the skin. The microwave attenuation and phase characteristic of normal breast tissue is such that constructive addition is possible for wide-bandwidth backscattered returns using broad aperture confocal-imaging techniques. The confocal technique suppresses returns from spurious scatterers such as a vein interposed between the tumor and the surface of the breast.

1.2 Breast Tissue Dielectric Properties

Dielectric Contrast between Malignant Tumors and Surrounding Normal Breast Tissue

Measurements of 30 different tissue types by Gabriel *et al.* [1]–[4] indicate that the relative dielectric permittivity ε_r, and conductivity σ, of high-water-content tissues (such as muscle or malignant tumors) are about an order of magnitude greater than those of low-water-content tissues (such as fat or normal breast tissue). As illustrated in figures 1 and 2, this contrast between high- and low-water-content tissues persists over the entire radio frequency (RF) spectrum from power frequencies through millimeter waves.

Joines e*t al.* [5] measured to 0.9 GHz the ε_r, and σ of freshly excised tissues from the colon, kidney, liver, lung, breast, and muscle. Each tissue sample was taken from four to seven different patients, and each sample was measured at three different positions. Chaudhary *et al.,* [6] measured to 3GHz the ε_r, and σ of normal and malignant breast tissues obtained from 15 patients. The data of Joines *et al.,* at 0.9

GHz indicates that of malignant breast tumors exceeds that σ of normal breast tissue by 6.4: 1, and ε_r of malignant breast tumors exceeds that of normal breast tissue by 3.8: 1. Joines *et al.* further found that for breast tissues of the same type, the dielectric contrast between malignant and normal tissues is greatest for the mammary gland. The data of Chaudhary *et al.* up to 3 GHz indicate corresponding malignant tumor-to- normal breast tissue ratios of 4.7: 1 and 5: 1, in good agreement with Joines *et al.*

1.2.1 Malignant Tumor Properties

Foster and Schepps [7], Rogers *et al.* [8], and Peloso *et al.* [9] separately measured ε_r and σ of malignant tumors and found values above 1 GHz that are almost the same as for normal high-water-content tissues such as muscle. In some cases, ε_r and σ for malignant tumors were significantly greater than for normal muscle tissues, especially at frequencies below 1 GHz [10].

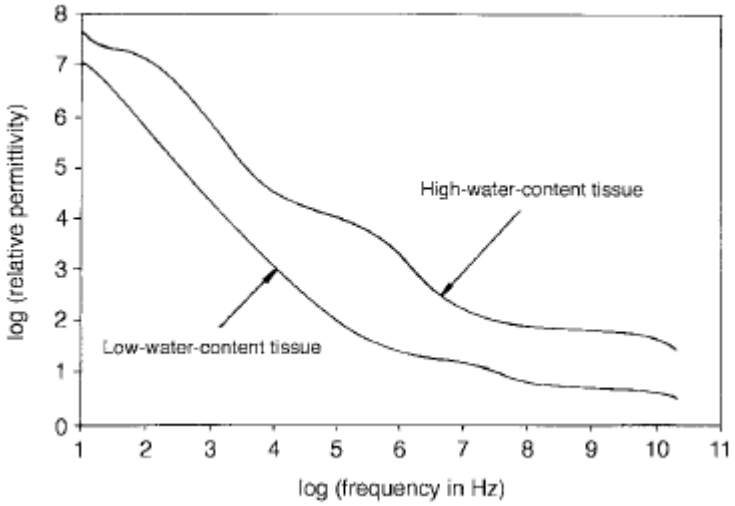


Figure 1: Comparison of the permittivity of high-water content tissue such as muscle with low- water content tissue such as fat as a function of frequency according to Gabriel et al

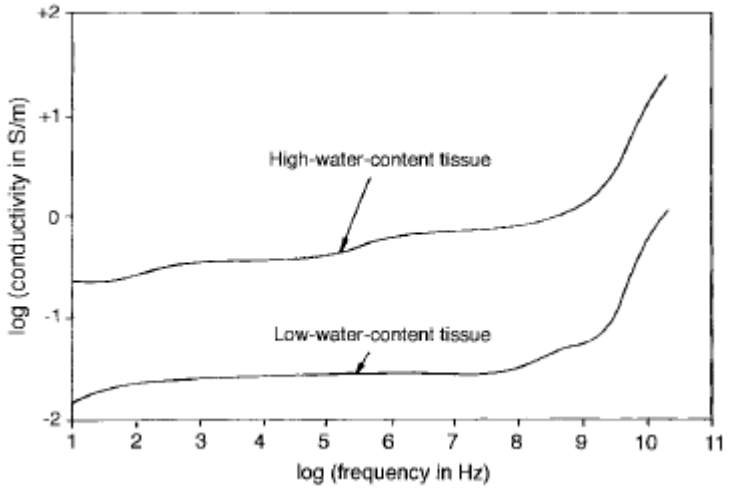


Figure 2: Comparison of the conductivity of high-water content tissue such as muscle with low- water content tissue such as fat as a function of frequency according to Gabriel et al.

Swarup *et al.* [10] studied the onset of the high values of ε_r and σ in malignant tumors by measuring MCA1 fibro sarcoma mouse tumors at 7, 15, and 30 days after inception. No significant variation of ε_r and σ was seen with tumor age. While the larger tumors exhibited a necrotic interior, they showed little difference in ε_r and σ above 0.5 GHz.

Surowiec *et al.* [11] performed measurements of cm-size malignant human breast tumors and adjacent tissues and found an increase in ε_r and σ of the normal breast tissue near malignant tumors. This effect

may be caused by infiltration or vascularization. It could enlarge the microwave scattering cross-section and thereby aid in the confocal microwave detection of the tumor.

1.2.2 Skin and Veins

Gabriel *et al.* found that, for either wet or dry skin, $30 < \varepsilon_r < 40$ and $1 < \sigma < 10$ S/m from 1–10 GHz. While some dielectric property data exist for blood, none can be found for vein walls. For computational models, you can assume that the dielectric properties of a vein are the same as those of muscle.

1.2.3 Breast Geometry

The depth of a typical normal, non-lactating human breast is about 5 cm [12]–[14]. This suggests that a mildly compressed breast would span less than 5 cm between the skin surface and the rib cage. Further, almost 50% of all breast tumors occur in the quadrant near the armpit where the breast is less than about 2.5-cm deep.

1.3 Finite Difference Time Domain (FDTD)

The FDTD technique is used in solving electromagnetic scattering problem, because it can model an inhomogeneous object of arbitrary shape. It is a time domain numeric electromagnetic technique for solving Maxwell's equations. The Maxwell's equations are discretized in space and time. This is accomplished by mapping the volume of interest onto rectangular grid where the unknown field components are located in each cell. FDTD algorithm explicitly solves Maxwell's curl equations using central finite differences in both time and space. The FDTD grid is composed of rectangular boxes (called Yee cells). Each box edge is an electric field location, and the material for each mesh edge can be specified independently of other edges and each face is a magnetic field location. Assigning different materials to different mesh edges forms the geometry. Regular grid is chosen since making calculations for each grid is extremely fast. This allows precise approximations to the actual physical geometry.

FDTD method is a time stepping procedure. Inputs are time-sampled analog signals. By alternately calculating the electric and magnetic fields at each time step, fields are propagated throughout the mesh. The time-dependent differential form equations are given by,

$$\times = -- \quad (1)$$

$$\times = --+ \quad (2)$$

1.3.1 2-D FDTD Analysis of a Pulsed Microwave Confocal System for Breast Cancer Detection

1.3.2 Modeling of the Fixed Focus Elliptical System

As the first step in the systems analysis, a fixed focus confocal microwave system employing a metal elliptical reflector was computationally modeled in two dimensions using the finite-difference time-domain (FDTD) solution of Maxwell's equations, for the transverse magnetic case. The reflector was specified with one focal point at a monopole antenna element and one in a breast half-space 3.8 cm below the surface. (In such two-dimensional (2-D) models, all material structures in the computational space, including the antenna, are assumed to be infinitely long. Thus, there is no ground return for the antenna and it is termed a "monopole.")

Figure 3 illustrates the FDTD model of this system. This model used a uniform grid with square unit cells as fine as 0.2 mm in the highest-resolution simulations. The reflector was assumed filled with lossless dielectric ($\varepsilon_r = 9$, $\sigma = 0$) matching the nominal breast permittivity, and was located at the surface of a

half-space of normal breast tissue ($\varepsilon_r = 9$, $\sigma = 0.4$ S/m). No skin layer was modeled. The monopole antenna was excited by a 270-ps Gaussian pulse multiplying a 6-GHz sinusoid that passed through zero at the peak of the Gaussian. This signal has zero dc content and a Gaussian, double sideband (DSB) suppressed-carrier spectrum symmetric about 6 GHz. The full-width spectral bandwidth at half-maximum extends from 4 to 8 GHz. A circular tumor extends from 4 to 8 GHz. A circular tumor ($\varepsilon_r = 50$, $\sigma = 7$ S/m) was assumed located at the in-breast focus.

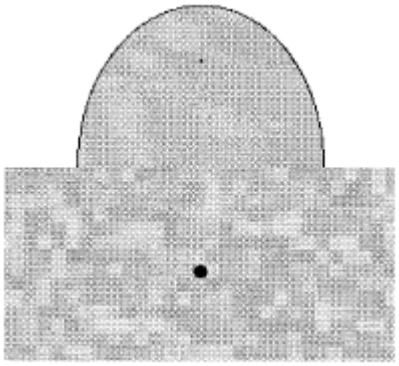


Figure 3: 2-D FDTD Computational model of the elliptical reflector system showing the heterogeneous breast tissue model and 0.5cm diameter tumor located at the in breast focus 3.8cm beneath the surface

1.3.3 ± 10% Random Heterogeneity of the Normal Breast Tissue

To simulate the heterogeneity of the normal breast tissue as measured by Joines *et al.* [5] and Chaudhary *et al.* [6], 10% random fluctuations of ε_r and σ were assigned to the breast tissue half-space in a checkerboard pattern. Specifically, as shown in Fig.3, each square block of grid cells spanning 5×5mm was randomly assigned a value of ε_r and a value of σ in a 10% range centered about the nominal. This resulted in random, peak 20% jump discontinuities of the normal breast- tissue ε_r and σ at the scale of the tumor diameter. FDTD modeling was performed for a) no tumor present, to establish the background clutter; b) variable location of a tumor having a 0.5-cm fixed diameter; and c) variable diameter of a tumor having a fixed location at the in-breast focal point. The signal-to-clutter (S/C) ratio was obtained by comparing the peak backscattered responses of the heterogeneous breast model with and without the presence of the tumor.

Figure 4 depicts the calculated time waveforms of the backscattered power response for this model with and without the 0.5-cm-diameter tumor present at the in-breast focus 3.8 cm below the surface. Upon forming the ratio of the peak back scattered pulse amplitude with the tumor present to the peak back scattered pulse amplitude without the tumor present, the S/C ratio is found to be 12dB. Figure 5 graphs the calculated S/C for the 0.5-cm diameter tumor as a function of the tumor's lateral position from the focus for a constant depth of 3.8 cm. We infer from this figure that the lateral resolution in locating the tumor in the presence of the clutter is about 0.5 cm. Figure 6 graphs the calculated S/C for a tumor fixed in position at the in-breast focus as a function of the tumor's size. We infer from this figure that tumors having diameters as small as 0.2 cm can yield responses that are 12 dB above the background clutter due to the random ±10% tissue heterogeneity.

1.3.4 ± 20% Random Heterogeneity of the Normal Breast Tissue

The above study was repeated for an increased heterogeneity of the normal breast tissue of ± 20% about the nominal, more than twice which experimentally was observed by Joines *et al.* [5] and Chaudhary *et al.* [6]. This resulted in random, peak ±40% jump discontinuities of the normal-breast-tissue ε_r and σ at the scale of the tumor diameter. While the computed S/C ratios were reduced by 5–6 dB relative to the ±10% heterogeneity case, the S/C remained greater than 6 dB for tumor diameters of 0.2 cm or larger. Further, the systems lateral resolution was unchanged (about 0.5cm).

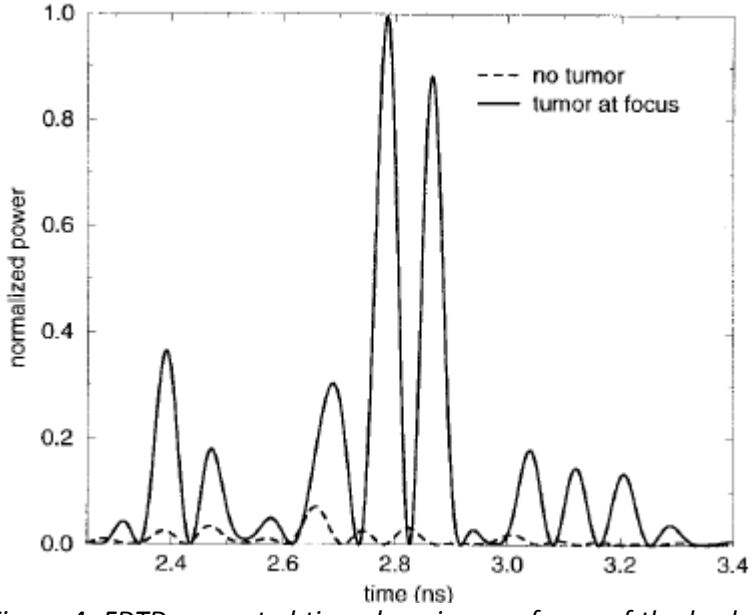


Figure 4: FDTD-computed time domain waveforms of the backscattered response with and without the 0.5cm diameter tumor present at the in-breast focus

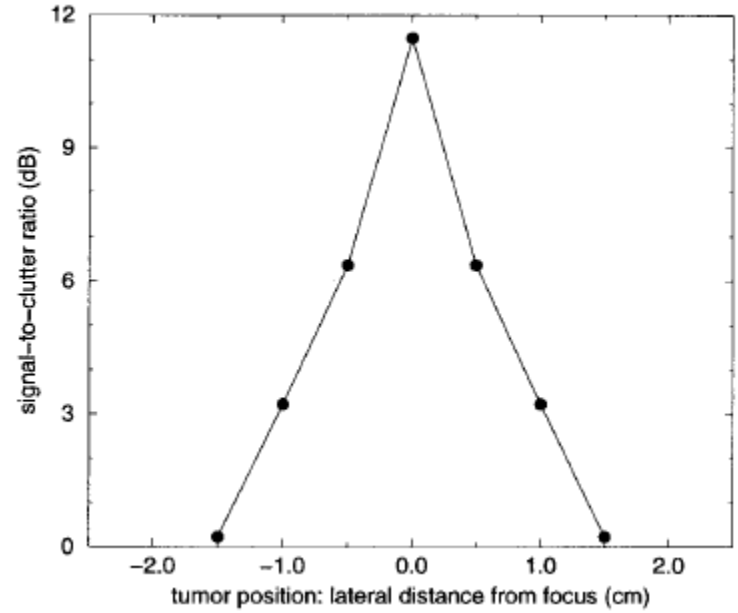


Figure 5: Signal to clutter (S/C) ratio for the back scattered response of the 0.5cm diameter tumor as a function of the tumor's lateral distance from the in-breast focus

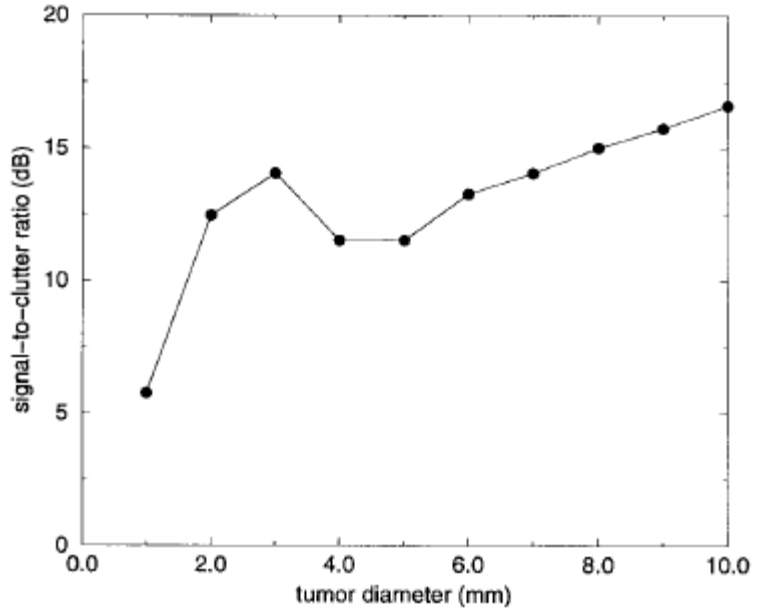


Figure 6: Signal to clutter (S/C) ratio for the backscattered response of a tumor at the in-breast focus as a function of tumor's size

1.4 Finite Volume Time Domain

The Finite-Volume Time-Domain (FVTD) method, as a general time-domain field solver, has successfully been applied to a variety of electromagnetic structures. The advantage of an unstructured mesh with tetrahedral volume elements places the FVTD method somewhat in between the Finite Element Time-Domain (FETD) method and the Finite-Difference Time- Domain (FDTD) method. Since the FVTD method is still in its infancy in computational electromagnetic application – at least in comparison to the FDTD method – the potential of this relatively new approach has not been fully unfolded yet. Although several authors have illustrated the capability of the FVTD method for the analysis of large scale problems [15] or problems with fine details surrounded by curved linear boundaries [16], the achievable accuracy for the FVTD method in particular for problems requiring a large dynamic range, has not been demonstrated so far. The FVTD method is inherently applied in unstructured meshes and thus is able to approximate complex geometries naturally without additional effort. In contrast, methods using structured meshes, e.g. a classic stair casing FDTD approach, may need to incorporate artificial treatment of boundaries to meet certain accuracy requirements.

1.4.1 Electromagnetic Wave Diffraction using a Finite Volume Method

Simulation of near fields scattered by an aircraft illuminated by an incident plane wave will be discussed. An exciting Gaussian pulse in the time domain is used for the following example in the computational time interval. The scatterer is assumed to be perfectly conductive. In Figs. 7 and 8, we present the meshes used for the numerical simulations. For the FDTD, the computational domain is composed of 4144000 volumes and for FVTD, the discretization leads to 79361 volumes with the same minimum mesh size. The results presented in Fig. 9 shows the x-component of the electric field and the y-component of the magnetic field computed at points A and B with the two methods. In this example the use of FVTD permits an important gain in memory and a gain of 3 in time compared with FDTD, despite a smaller time step to ensure the scheme's stability and a larger number of operations in FVTD than in FDTD.

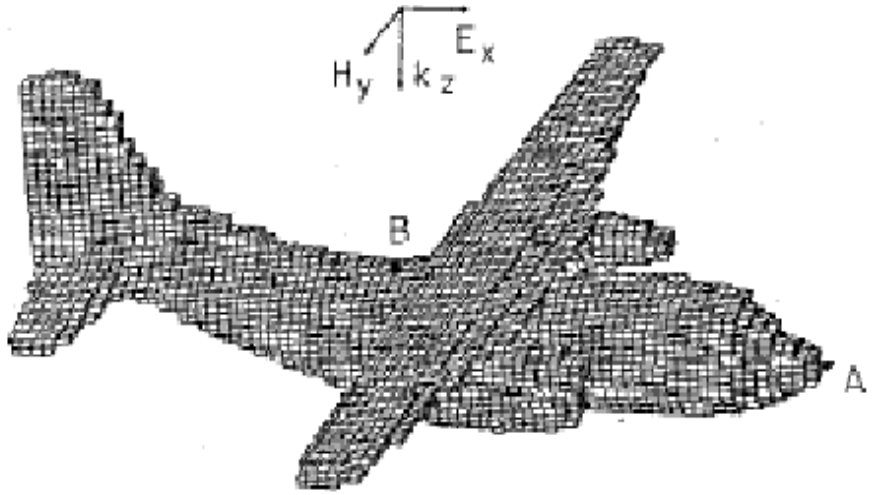


Figure 7: FDTD meshing

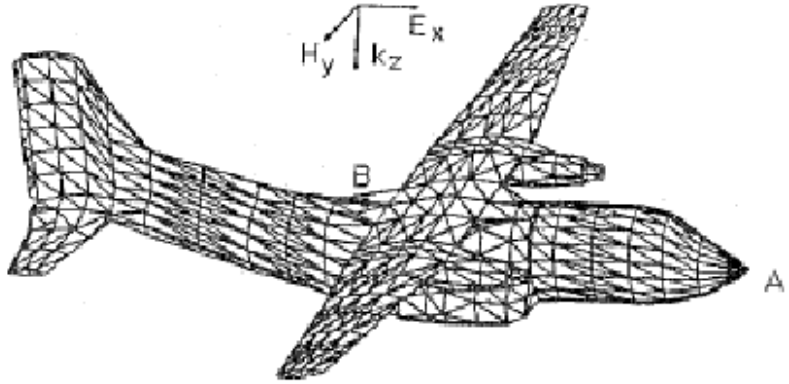
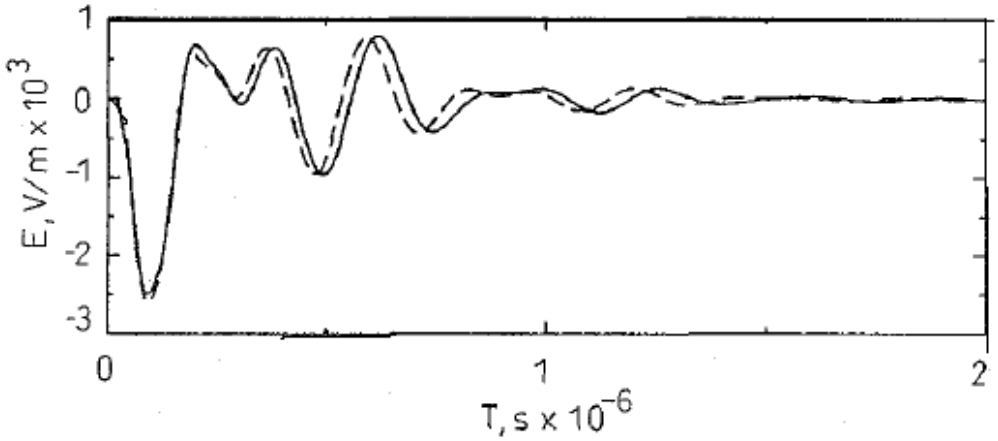
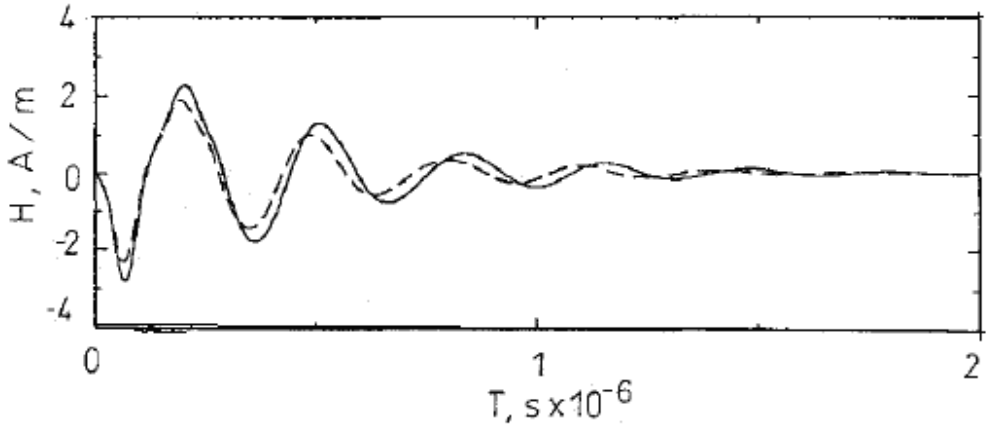


Figure 8: FVTD meshing





- - - - - FDTD

_____ FVTD

Figure 9: Comparison between FDTD and FVTD

1.5 Conclusion

The finite volume technique seems to be an interesting approach for the study of electromagnetic wave diffraction. Scatterers with 'complex' surfaces can be treated. The higher computational time required in FVTD can be compensated by a conformal unstructured meshing of the objects allowing local refinement mesh easier than in FDTD. Moreover with the finite volume scheme, thin material with finite conductivity and dielectric part can be taken into account easily.

References

C. Gabriel, (1996). “A compilation of the dielectric properties of body tissues at RF and microwave frequencies,” Radiofrequency Radiation Division, Brooks AFB, San Antonio, TX, Contract AL/OE TR-1996-0037.

C. Gabriel, S. Gabriel and E. Corthout (1996). “The dielectric properties of biological tissues: I. Literature survey,” *Phys. Med., Biol.,* **41**(11), pp. 2231–2249.

S. Gabriel, R. W. Lau and C. Gabriel, (1996). “The dielectric properties of biological tissues: II. Measurements on the frequency range 10 Hz to 20 GHz,” *Phys. Med., Biol.,* **41**(11), pp. 2251 2269.

W. T. Joines, Y. Z. Dhenxing and R. L. Jirtle, (1994). “The measured electrical properties of normal and malignant human tissues from 50 to 900 MHz,” *Med. Phys.,* **21**, pp. 547–550.

S. S. Chaudhary, R. K. Mishra, A. Swarup and J. M. Thomas, (1984). “Dielectric properties of normal and malignant human breast tissues at radiowave and microwave frequencies,” *Indian J. Biochem., Biophys.,* vol. **21**, pp. 76–79.

K. R. Foster and J. L. Schepps, (1981). “Dielectric properties of tumor and normal tissue at radio through microwave frequency,” *J. Microwave Power,* vol. **16**, pp. 107–119.

J. A. Rogers, R. J. Shepard, E. H. Grant, N. M. Bleehen and D. J. Honess (19830. “The dielectric properties of normal and tumor mouse tissue between 50 MHz and 10 GHz,” *Br. J. Radiol.,* vol. **56**, pp. 335-338.

R. Peloso, D. Tuma, and R. K. Jain (1984). “Dielectric properties of solid tumors during normothermia and hyperthermia,” *IEEE Trans. Biomed.Eng.,* vol. BME-31, pp. 725–728.

S. Swarup, S. S. Stuchly, and A. Surowiec,(1991). “Dielectric properties of mouse MCA1 fibro sarcoma at different stages of development,” *Bioelectromagn.,* vol. **12**, pp. 1–8.

A. J. Surowiec, S. S. Stuchly, J. R. Barr and A. Swarup (1988). “Dielectric properties of breast carcinoma and the surrounding tissues,” *IEEE Trans. Biomed. Eng.,* vol. **35**, pp. 257–263.

H. Gray, *Anatomy of the Human Body,* C. M. Goss, Ed. Philadelphia, PA: Lea and Febiger, 1949.

X. Wu, G. T. Barnes and D. M. Tucker, (1991). “Spectral dependence of glandular tissue dose in screen-film mammography, Radiol” vol. **179**, pp. 143–148.

M. Rosenstein, L. W. Andersen and G. Warner (1985). “Handbook of glandular tissue doses in mammography,” U.S. Government Printing Office, Washington, DC, HHS (FDA) Publication 858239.

P. Bonnet, X. Ferrieres, F. Paladian, J. Grando, J. Alliot and J. Fontaine (1997). “Electromagnetic wave diffraction using a finite volume method,” *IEE Electr. Letters*, vol. **33**(1), pp. 31–32.

Fumeaux, C., Baumann, D. and Vahldieck, R. (204). “Advanced FVTD simulations of dielectric resonator antennas and feed structures,” *ACES Journal*, vol. **19**(3), pp. 155–164.

GROWTH CHARACTERISTICS AND PRODUCTION OF SECONDARY METABOLITES FROM SELECTED NOVEL *STREPTOMYCES* SPECIES ISOLATED FROM SELECTED KENYAN NATIONAL PARKS

E. N. Karanja, H. I. Boga, A. W. Muigai, F. Wamunyokoli, J. Kinyua and J. O. Nonoh
[1]Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: hboga@fsc.jkuat.ac.ke

Abstract
The aim of study was to characterize growth of novel *Streptomyces* isolates as well as the secondary metabolites they were producing. Four Streptomyces isolates from Chyulu National Park (Chy 4-10, Chy 15-10, Chy 15-5 and Chy 2-3) and one from Ruma National Park (Ruj 7-1) were studied. The isolates grew well at pH 6, 7, 9 and temperatures of 27.5 ^{o}C, 30 ^{o}C, and 32.5 ^{o}C. They preferentially utilized glucose and xylose and also required sodium chloride (0 g/l – 17.5 g/l) for growth. Antimicrobial products were extracted using ethyl acetate and the crude secondary metabolite extracts analyzed using Gas Chromatography- Mass Spectrophotometer (GC-MS). 0.54 g/l, 0.62 g/l, 0.41 g/l, 0.3 g/l and 0.14 g/l yields of crude secondary metabolites were extracted from the isolates. The crude secondary metabolites had different levels of activity against Gram positive and Gram negative test bacteria. Characterization of the crude secondary metabolites indicated presence of chemical compounds ranging from amides, amines, acids, pyrrolizidines, butenolides, alcohols and hydrocarbons.

Key words: *Streptomyces,* antimicrobial activity, gas chromatography, mass Spectrophotometer, secondary metabolites

1.0 Introduction

Streptomyces are mostly filamentous bacteria that are widely distributed in a variety of natural and man-made environments. They constitute a significant component of the microbial population in most soils (Watve *et al*., 2001). They are about 1µm in diameter. Their colonies appear like a mass of unicellular mycelium, with branching filament extensions of the original cell or cells, in addition to spores and degradation products (Waksman, 1950). They reproduce by fission or by spores and this is why they were originally classified as fungi. The optimal pH range in which they grow is between 7 and 8. Most of them grow at temperatures between 15 and 30°C (Waksman, 1950, 1962 and 1967). They are also characterized by their gram-positive nature and high G-C content of their genomes and have an unparalleled ability to produce diverse secondary metabolites (Berdy, 2005).

Around 23,000 bioactive secondary metabolites produced by microorganisms have been reported and over 10,000 of these compounds are produced by Actinomycetes, representing 45% of all bioactive microbial metabolites discovered (Berdy, 2005). Among Actinomycetes, around 7,600 compounds are produced by *Streptomyces* species (Berdy, 2005).

Streptomyces produce chemically diverse secondary metabolites that are structurally related, as well as structurally unrelated types of secondary metabolites from the same culture. Production of these secondary metabolites is usually during the stationary or slower stages of growth (Alexandra, 1997). Their production however is increased by inducing a biosynthetic enzyme (synthase) or increasing the limiting factor. Much of the published data indicates that the most important environmental signal triggering secondary metabolism is nutrient starvation, particularly that of phosphate (Sola-Landa *et al.,* 2003). The signaling networks behind the regulation of secondary metabolism in Streptomyces have recently been reviewed (Bibb, 2005).

Many of these secondary metabolites are potent antibiotics, which has made Streptomycetes the primary antibiotic-producing organisms exploited by the pharmaceutical industry (Berdy, 2005). Members of this group are producers, in addition, of clinically useful antitumor drugs such as anthracyclines (aclarubicin, daunomycin and doxorubicin), peptides (bleomycin and actinomycin D), aureolic acids (mithramycin), enediynes (neocarzinostatin), antimetabolites (pentostatin), carzinophilin, mitomycins (Newman and Cragg, 2007; Olano *et al.,* 2009).

However, besides antibiotics which present the largest group of bioactive secondary metabolites, the Streptomycetes compounds show several other biological activities. These are: firstly, antagonistic agents that include; antibacterials, antifungals, antiprotozoans as well as antivirals: secondly, pharmacological agents that shows the following activities; antitumor, immunomodulators, neurological agents and enzyme inhibitors: thirdly, agrobiologicals comprising of; insecticides, pesticides and herbicides: fourthly, compounds with regulatory activities such as; growth factors, siderophores or morphogenic agents (Sanglier *et al.,* 1996; Berdy 1995, 2005) (Table 1).

Table 1: Examples of antibiotics produced by Streptomyces sp. (Kieser et al., 2000)

Antibiotic	Producer	Chemical Class	Target	Application
Actinomycin D	*Streptomyces* sp.	Peptide	Transcription	Antitumor
Actinomycin A	*Streptomyces* sp.	Macrolide	Cytochrome system	Telocidal
Avermectin	*S. avermetilis*	Macrolide (PK)	Chloride ion channels	Antiparasitic
Daptomycin	*S. roseosporus*	Lipopeptide	Lipoteichoic acid	Antibacterial
Nystatin	*S. noursei*	Polyene	Membrane (pore former)	Antifungal
Nikkomycin	*S. tendae*	Nucleoside	Chitin biosynthesis	Antifungal; insecticidal
Neomycin	*S. fradiae*	Aminoglycoside	Protein synthesis	Antibacterial
Phleomycin	*S. verticillus*	Glycopeptide	DNA strand breakage	Antitumor
Polyoxins	*S. cacaoi var asoensis*	Nucleoside-peptide	Chitin biosynthesis	Antifungal

Due to the ability in synthesizing numerous compounds that exhibit extreme chemical diversity, *Streptomyces* strains have become a major part of industrial strain collection used in screening for new bioactive molecules (Demain and Davies, 1999). This study was therefore geared towards unveiling and assessing novel secondary metabolites that could be of commercial importance hence improving industrial and pharmaceutical applications as well as in other sectors where they may be of use.

2.0 Materials and Methods

2.1 Growth of *Streptomyces* Isolates

The isolates were fermented in a differential broth media in a shaker incubator (Gallen Kamp, Germany) (200 rpm, 28ºC) for 96 h. The original stocks of the isolates from which the working stocks were prepared were kept in a freezer (Sanyo MDF-594 AT, Japan) at - 80°C.

2.2 Physiochemical Characterization of the Actinobacteria Isolates

In order to carryout screening and extraction of antimicrobial compounds from the isolates, optimization of growth conditions and media composition was done to achieve good results.

2.2.1 Sugar Fermentation

Sugar fermentation test was carried to determine the ability of the isolates to degrade and ferment various carbohydrates. Bromothymol blue (Sigma Aldrich, Germany) dye was added to basal broth media containing the various sugars, inoculated with the isolates and incubated in a shaker incubator (Gallen Kamp, Germany) (30°C for 96 h at 100rpm). Utilization of the various sugars was ascertained by growth of the isolates. This was determined by measuring the optical densities of the broth cultures using a UV spectral photometer (Shimadzu UV 240, Japan) at 600nm (Williams *et al*., 1989).

2.2.2 Effect of pH on Growth of the Actinobacteria Isolates

An optimum pH requirement for the isolates was determined. International Streptomyces Project (ISP_2) broth media adjusted to varying pH ranges of 3, 6, 7 and 9, using 1N sodium hydroxide and 1N hydrochloric acid was used. The cultures were incubated in a shaker incubator (Gallen Kamp, Germany) (30ºC for 48 h at 100rpm) and optical density readings were read at 600nm using a UV spectral photometer (Shimadzu UV 240, Japan).

2.2.3 Effect of Temperature on Growth of the Actinobacteria Isolates

Growth of the five isolates was monitored by spectrophotometric measurement of the optical density at 600 nm. Experiments were performed at 15, 20, 25, 27.5, 30, 32.5, 35, 36, 37, and 38°C. Prior to the experiments, bacteria were acclimatized to the temperature conditions in the growth experiments. All cultures were grown in liquid International Streptomyces Project (ISP_2) media on a rotary shaker incubator (Gallen Kamp, Germany) (15, 20, 25, 27.5, 30, 32.5, 35, 36, 37, and 38°C for 12 h at 100 rpm) in the dark. Precultures of acclimatized strains that were used for setting up growth experiments were grown overnight. Experiments were performed in 100-ml Erlenmeyer flasks in triplicate for each isolate. The medium used for the experiments was preincubated in a flat bed incubator for 6 h under the same temperature conditions as the temperature conditions in the experiment. Measurement of the optical density was started 72 h after inoculation. The optimal growth temperature was determined graphically.

2.2.4 NaCl tolerance Test

For this test, NaCl broth was used. 50 ml of the medium was autoclaved at 121°C for 15 min in clean 100 ml conical flasks. 100µl of test strain inoculums were inoculated into the medium contained in conical flasks and incubated on rotary shaker (Gallen Kamp, Germany) (30°C for 96 h at 100 rpm). Growth of the five isolates was monitored spectrophotometrically by measuring the optical density at 600 nm.

2.3 Extraction of Secondary Metabolites

Differential broth cultures of the isolates were prepared in 500 ml conical flasks and incubated in a rotary shaker (Gallen Kamp, Germany) (at isolate's optimum temperature for 240 h at 100 rpm). Filtration of the broth cultures by use of Whatman filter paper no.1 was done after fermentation to remove bacterial cells. The cell free culture filtrates were extracted three times with ethyl acetate at volume ratio of 1:1 by use of a separating funnel.

The extract was passed through a pad of anhydrous sodium sulphate to remove excess water and thereafter evaporated to dryness using a rotary vacuum evaporator (RE 100B, Bibby Sterilin, United Kingdom). Yields of the extracts were determined and recorded. The crude extracts were used for biological activity tests as well as Gas Chromatography- Mass Spectrophotometry (GC-MS) analysis of the compounds contained in them.

2.4 Bio Assay of the Crude Extracts Against Gram –ve and +ve Bacteria

Agar diffusion method was used to determine antibacterial activity of the crude extracts. The bacteria used comprised, *Escherichia coli* (NCTC 10418) and *Staphylococcus aureus* (NCTC 10788). Paper discs were prepared and impregnated with 10 µl of the sample crude extract prepared by dissolving the dry crude extracts in 1 ml ethyl acetate. The impregnated paper discs were allowed to dry in a fume chamber and then placed on agar seeded with the test organisms. Incubation was done in a flat bed incubator (Carbolite 301 Controller, Jencons, United Kingdom) (37 ºC for 24 h) and diameters of zones of inhibitions measured using a ruler and recorded.

2.5 GC-MS Analysis of Secondary Metabolites from the Actinobacteria Isolates

Chemical screening of the active compounds present in the crude extracts was done by use of a GC-MS (Figure 2.10) to detect the active compounds as well as their quantity and quality ratios. Each samples was reconstituted using 1ml DCM (Dichloromethane (≥99.8%; Aldrich chemical co. ltd., USA.) and passed through a glass wool to remove solid materials. 40 µl of the collection in triplicate was transferred into auto sampler glass vials having Teflon caps and analyzed using GC-MS whose conditions are given below (Table 2.10 a and b).Agilent Technologies 7890A system was used. Oven conditions set during the analysis were: 1 minute for equilibration time; 35 °C for 5 minutes, 10 °C/minute to 280 °C for 10.5 minutes and 50 °C/min to 285 °C for 9.9 minutes as the oven program while the running time was 50 minutes. Injection was done in splitless mode and the conditions used were as follows: 250 °C for the heater, 8.8271 Psi as the pressure, a total flow of 10.2 ml/ min, septum purge flow of 3 ml/ min, gas saver at 20 ml/ min after 2 minutes and Purge flow to split vent at 6mL/ min at 0.8minutes. The column used was HP-5MS, (5% methyl silox), (30 m × 250 µm × 0.25 µm) .The compounds identified were generated from a computer program that involved calculation by the data system of a similarity index, match factor or purity between the unknown spectrum and library (reference) spectra. For this analysis, NIST/EPA/NIH MASS SPECTRAL LIBRARY (NIST 05) and NIST MASS SPECTRAL SEARCH PROGRAM Version 2.0d were used.

2.6 Data Analysis

ANOVA tests were used to analyze the data. SAS 9.1 version was the software used to perform the analysis and separation of means was done by use of Tukeys' test. Means were used to draw graphs and tables.

3.0 Results

3.1 Physiochemical Characterization

3.1.1 Utilization of Sugars by the Isolates

Glucose resulted in highest growth of isolate Chy 4-10 (OD_{600}= 0.601nm). However, sucrose (OD_{600}= 0.473nm) and xylose (OD_{600}= 0.383nm) also led to a considerable growth of the isolate. (Figure 1a)

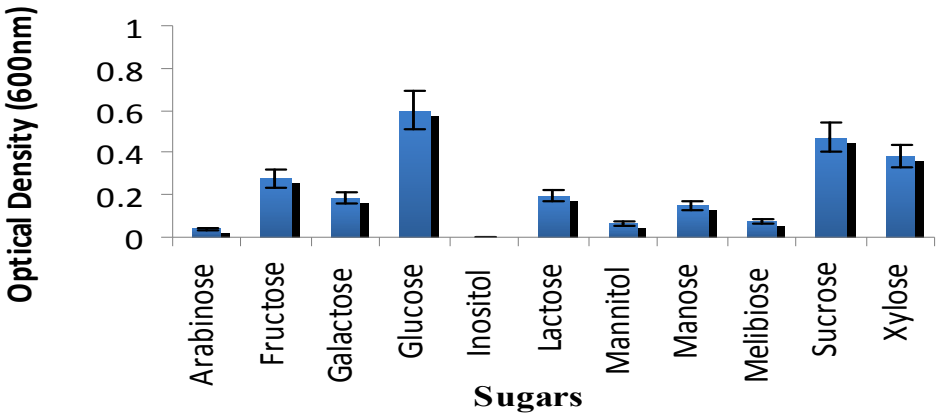


Figure 1a: Utilization of sugars by isolate CHY 4-10. ($P < 0.05$)

For isolate Chy 15-10, xylose led to highest growth (OD_{600}= 0.899nm). It provided optimum growth whereas mannitol (OD_{600}= 0.010nm), inositol (OD_{600}= 0.017nm), lactose (OD_{600}= 0.019nm) and arabinose (OD_{600}= 0.037nm) did not support high growth of the isolate. Glucose (OD_{600}= 0.509nm) and mannose (OD_{600}= 0.499nm) were also utilized although growth of the isolate was at a lower level from xylose (Figure 1b).

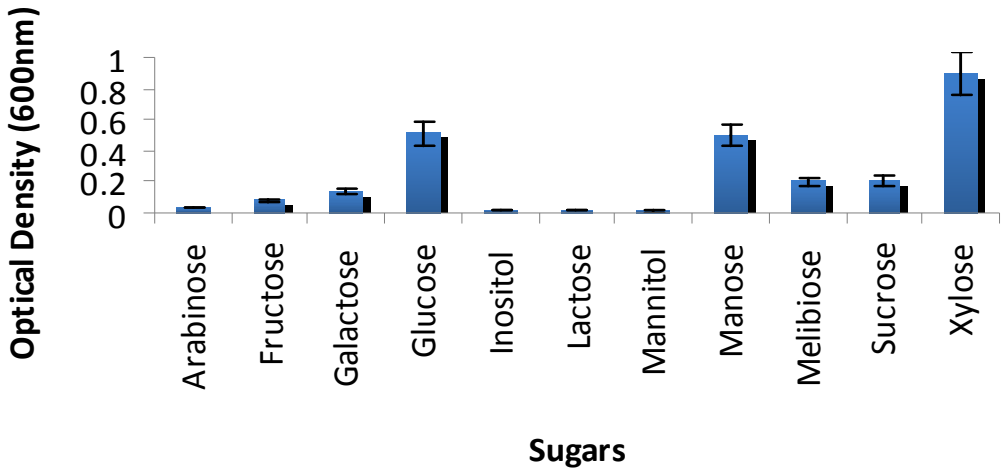


Figure 1b: Utilization of sugars by isolate CHY 15-10. (P < 0.05)

For isolate Chy 15-5, glucose had the highest growth (OD_{600}= 0.719nm) compare to the other sugars. Considering the difference in growth between the various sugars, optimum growth for the isolate would only be realized with glucose as the carbon source (Figure 1c).

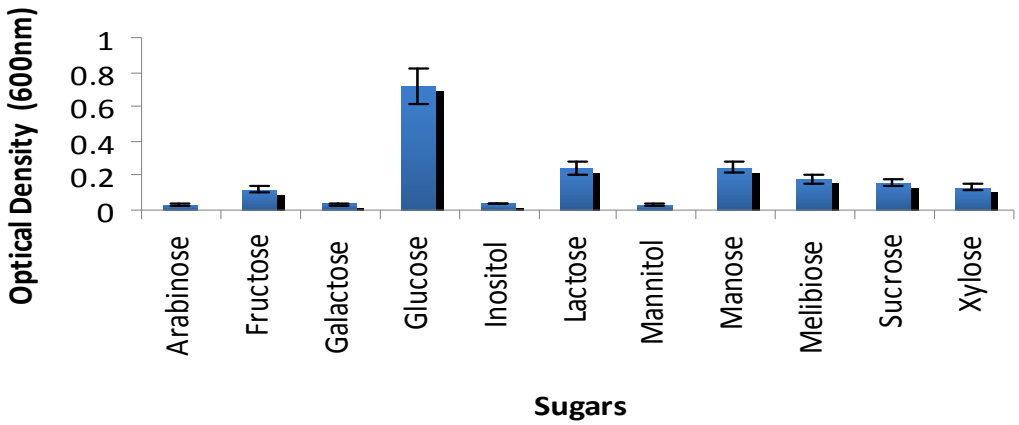


Figure 1c: Utilization of sugars by isolate CHY 15-5. (P < 0.05)

For isolate Chy 2-3, glucose (OD_{600}= 0.475nm) similarly led to high growth whereas mannitol (OD_{600}= 0.021nm) led to lowest growth of the isolate (Figure 1d).

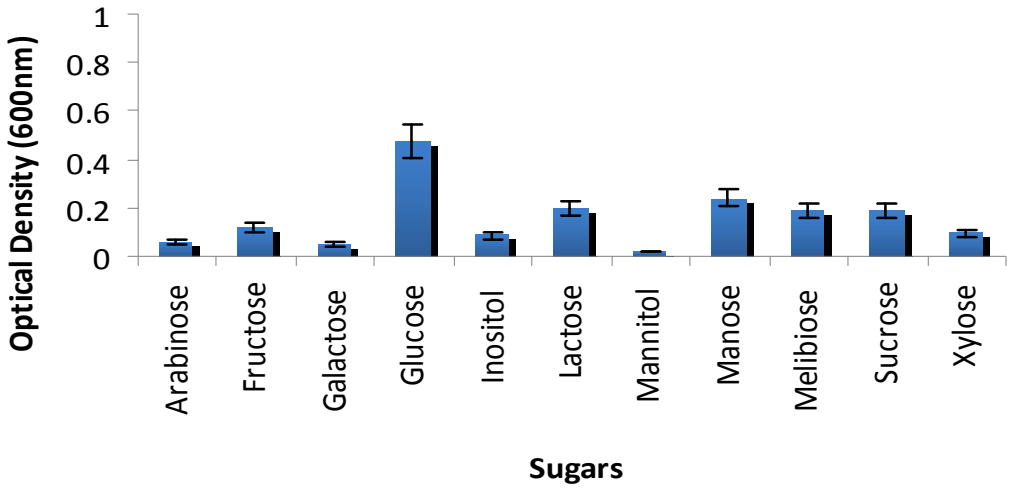


Figure 1d: Utilization of sugars by isolate CHY 2-3. (P<0.05)

And finally for isolate Ruj 7-1, xylose supported high growth (OD_{600}= 0.900nm) followed by glucose though at a much lower optical density (OD_{600}= 0.325nm) (Figure 1e).

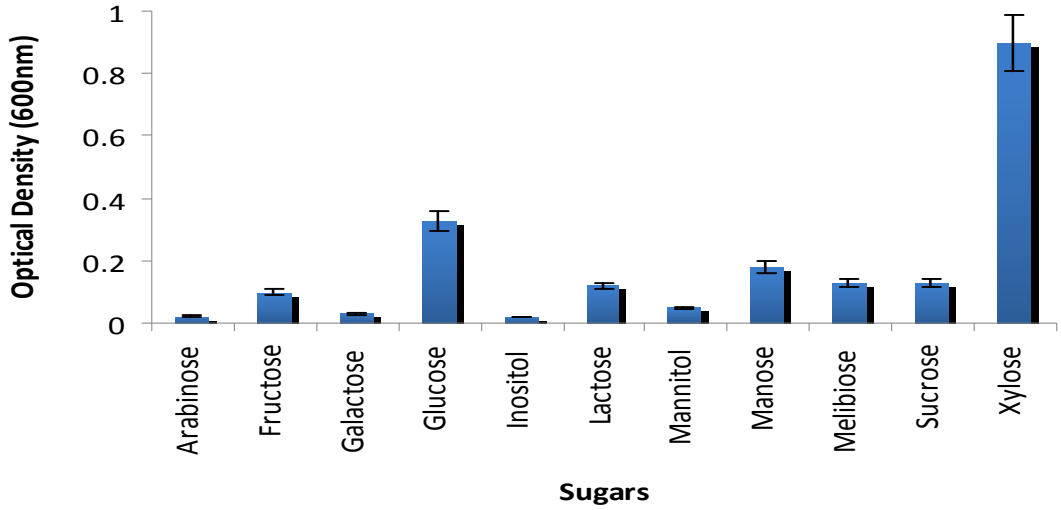


Figure 1e: Utilization of sugars by isolate RUJ 7-1. (P < 0.05)

3.1.2 PH tolerance by the Isolates

All the isolates were able to grow at acidic, neutral and alkaline pH conditions. However, the different pH conditions yielded different growth levels for the various isolates. PH 7 led to highest growth of isolate Chy 4-10 with an optical density (OD_{600}= 0.604nm). Lowest growth of the isolate was yielded at pH 3 (OD_{600}= 0.173nm) (Figure 2a). Increased growth of isolate Chy 15-10 was yielded at pH 9 (OD_{600}= 0.610nm) whereas minimal growth was at pH 3 (OD_{600}= 0.178nm) (Figure 2b). For isolate Chy 15-5, pH 9 (OD_{600}= 0.591nm) led to the highest growth of the isolate followed by pH 7 (OD_{600}= 0.549nm). Minimal growth of the isolate was yielded at pH 3 (OD_{600}= 0.205nm) (Figure 2c). For isolate Chy 2-3, increased growth of the isolate was yielded at pH 9 (OD_{600}= 0.489nm) whereas pH 3 had the lowest growth with an optical density (OD_{600}= 0.193nm) (Figure 2d). Lastly, highest growth of isolate Ruj 7-1was yielded at pH 6 (OD_{600}= 0.619nm) whereas minimal growth was at pH 3 (OD_{600}= 0.215nm) (Figure 2e).

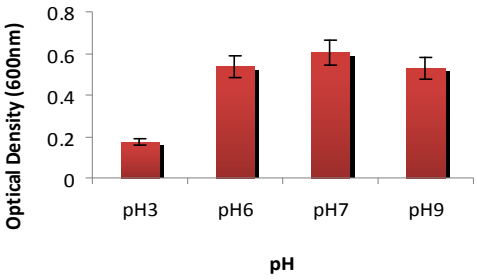


Figure 2a: Effect of pH on growth of the isolate CHY 4-10. (P<0.05)

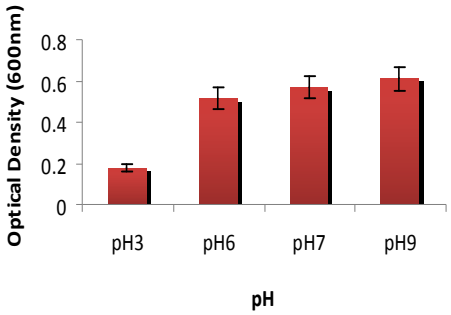


Figure 2b: Effect of pH on growth of the isolate CHY 15-10.

(P<0.05)

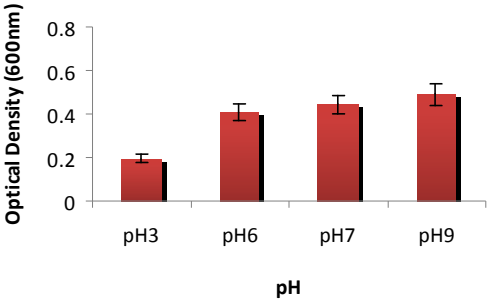


Figure 2c: Effect of pH on growth of the isolate CHY 15-5. (P<0.05)

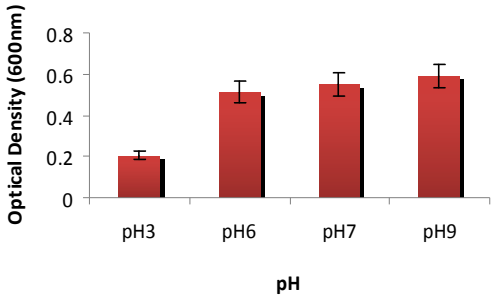


Figure 2d: Effect of pH on growth of the isolate CHY 2-3. (P<0.05)

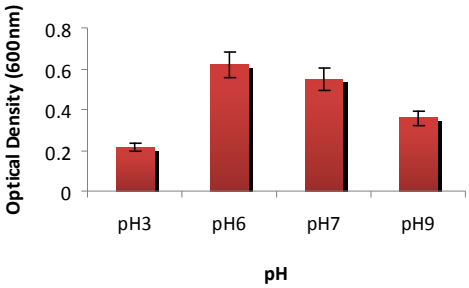


Figure 2e: Effect of pH on growth of the isolate RUJ 7-1. (P<0.05)

3.1.3 Temperature Tolerance by the Isolates

In all the isolates investigated, there was a linear increase in the temperature-dependent growth curves at the temperature range 15 °C to 32.5 °C. With further increases in temperature, the growth curves showed either a plateau or a linear decrease. The optimal growth temperature had the highest OD at 600nm. The optimum growth temperature for isolate Chy 4-10 was 30 °C (OD_{600}=0.610nm). Beyond 30 °C, there was a decline in growth of the isolate (Figure 3a). For isolate CHY 15-10, 32.5 °C (OD_{600}=0.602nm) was the optimum temperature for growth of the isolate (Figure 3b) whereas 30 °C (OD_{600}=0.562nm) was the optimum temperature for growth of isolate Chy 15-5 (Figure 3c). For isolate Chy 2-3, the optimum temperature for growth was 32.5 °C (OD_{600}=0.518nm) (Figure 3d). Lastly, 27.5 °C was the optimum temperature for growth of isolate Ruj 7-1 as it gave the highest growth (OD_{600}=0.653nm) when compared with other temperature regimes (Figure 3e).

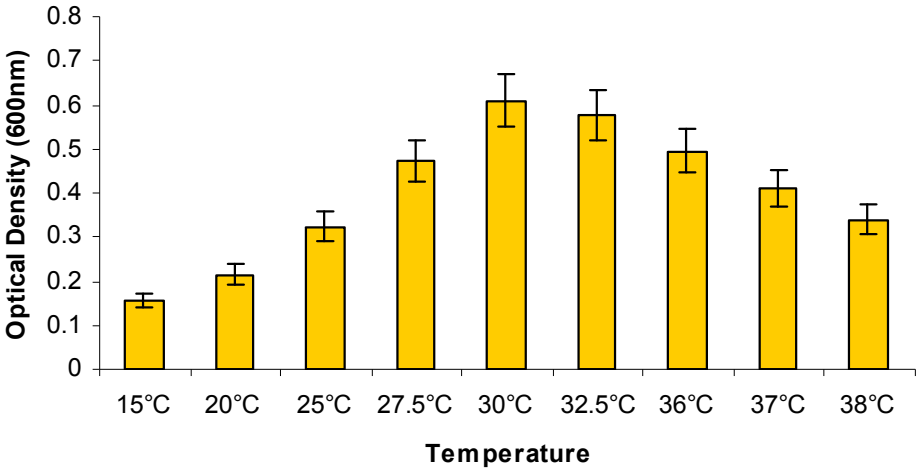


Figure 3a: Growth of isolates Chy 4-10 under different temperature ranges. (P<0.05)

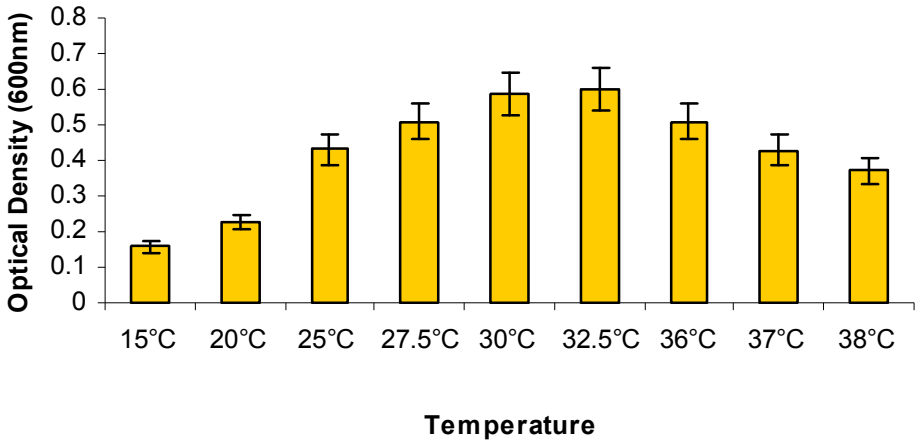


Figure 3b: Growth of isolates Chy 15-10 under different temperature ranges. (P<0.05)

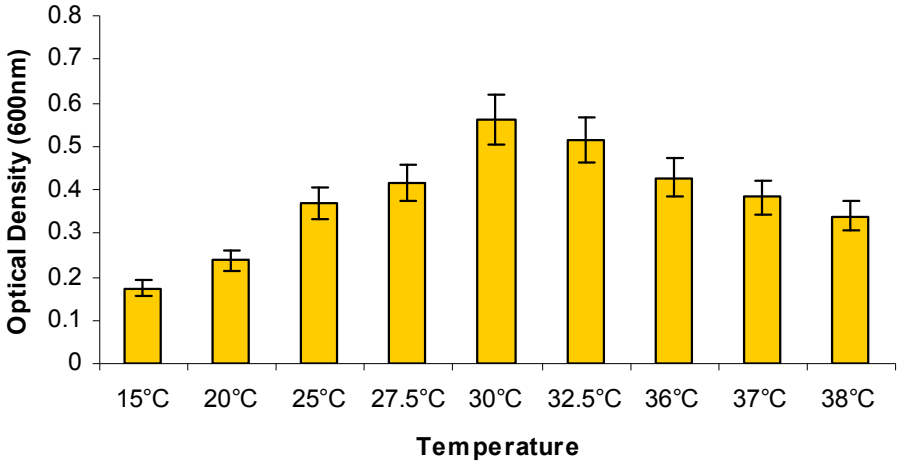


Figure 3c: Growth of isolates Chy 15-5 under different temperature ranges. (P<0.05)

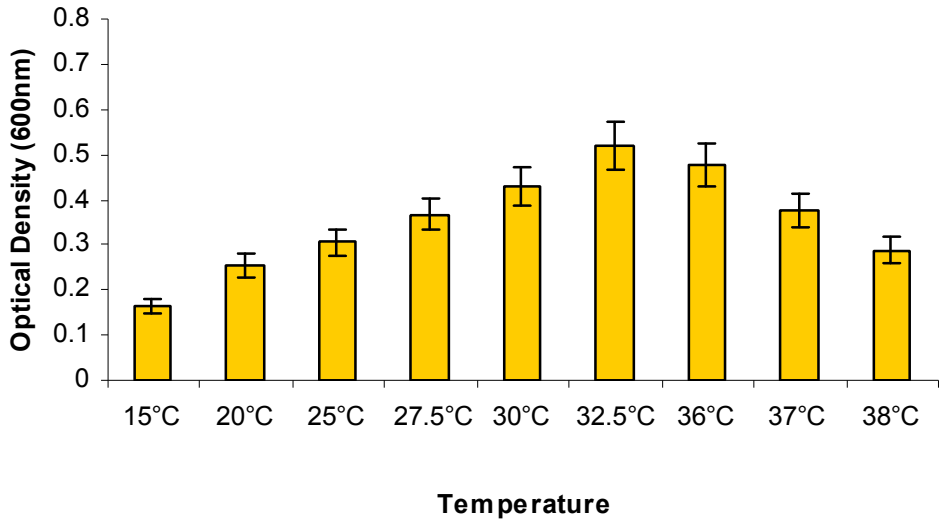


Figure 3d: Growth of isolates Chy 2-3 under different temperature ranges. (P < 0.05)

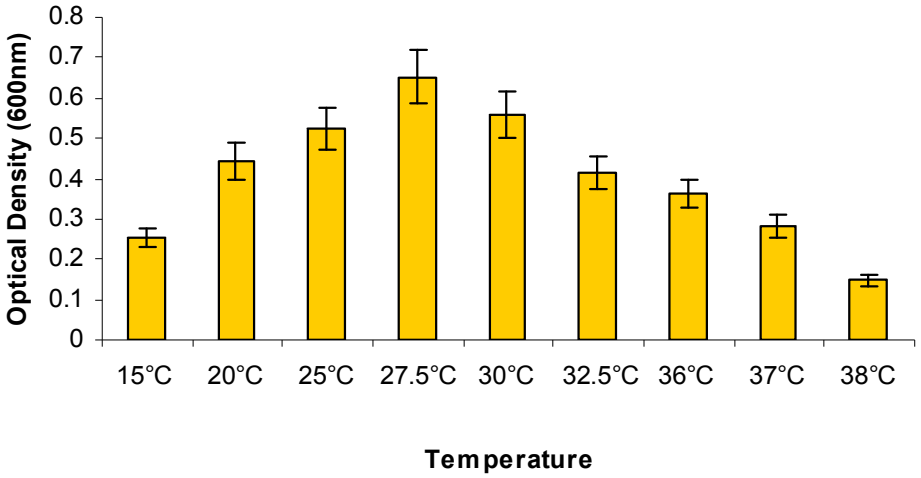


Figure 3e: Growth of isolates Ruj 7-1 under different temperature ranges. (P < 0.05)

3.1.4 NaCl Tolerance by the Isolates

Isolates were subjected to different sodium chloride concentrations to determine the concentration for optimum growth for each isolate. All the isolates were observed to utilize sodium chloride for growth. Optimum growth for isolate Chy 4-10 was achieved in 5 g/l (OD_{600}=0.411nm) whereas the lowest growth was recorded in 32.5 g/l (OD_{600}=0.026nm) concentration (Figure 4a). 5 g/l (OD_{600}=0.423nm) gave the highest growth of isolate Chy 15-10. Lowest growth on the other hand was recorded in 32.5 g/l (OD_{600}=0.010nm) concentration (Figure 4b). Sodium chloride concentration that recorded highest growth of isolate Chy 15-5 was 10 g/l (OD_{600}=0.169nm) whereas 32.5 g/l (OD_{600}=0.023nm) was the concentration with the lowest growth of the isolate (Figure 4c). For isolate Chy 2-3, optimum growth was recorded in 5 g/l (OD_{600}=0.388nm) whereas lowest growth was at 32.5 g/l (OD_{600}=0.009nm) concentration (Figure 4d). And lastly, optimum growth of isolate Ruj 7-1 was recorded in 17.5 g/l (OD_{600}=0.584nm) sodium chloride concentration (Figure 4e).

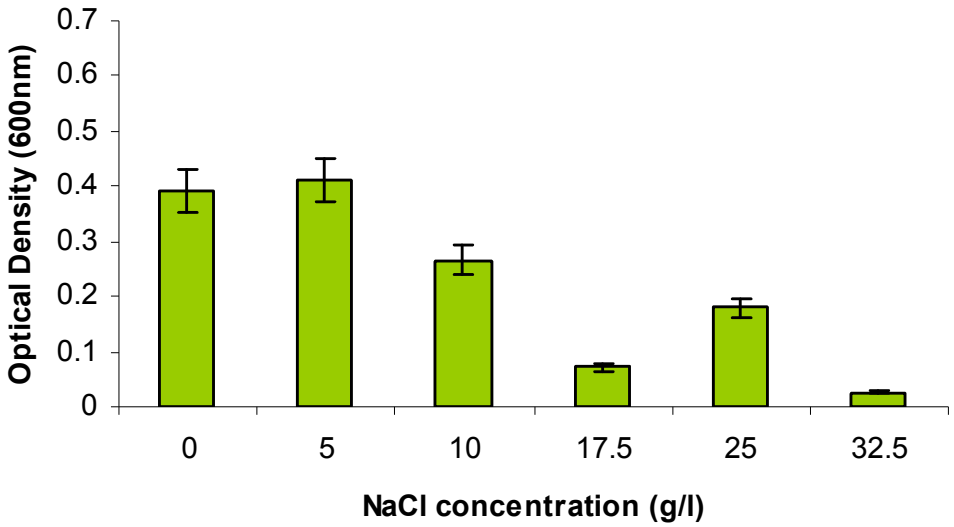


Figure 4a: Growth of isolate Chy 4-10 under different sodium chloride concentrations (P<0.05).

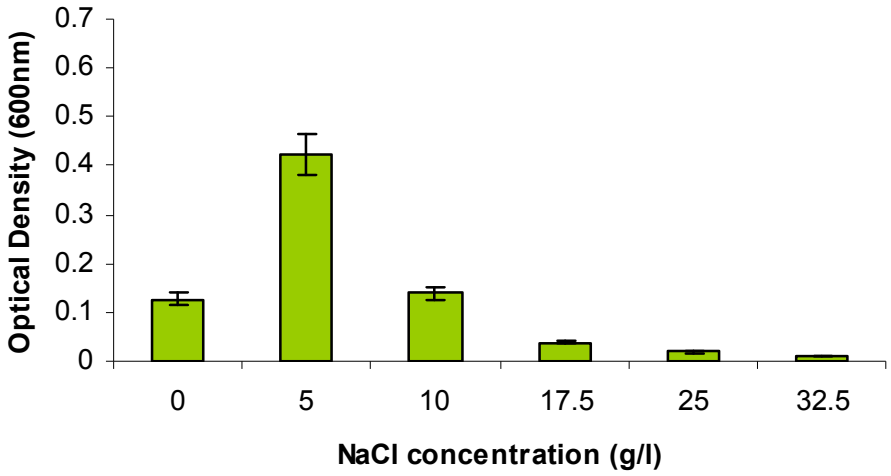


Figure 4b: Growth of isolate Chy 15-10 under different sodium chloride concentrations (P<0.05)

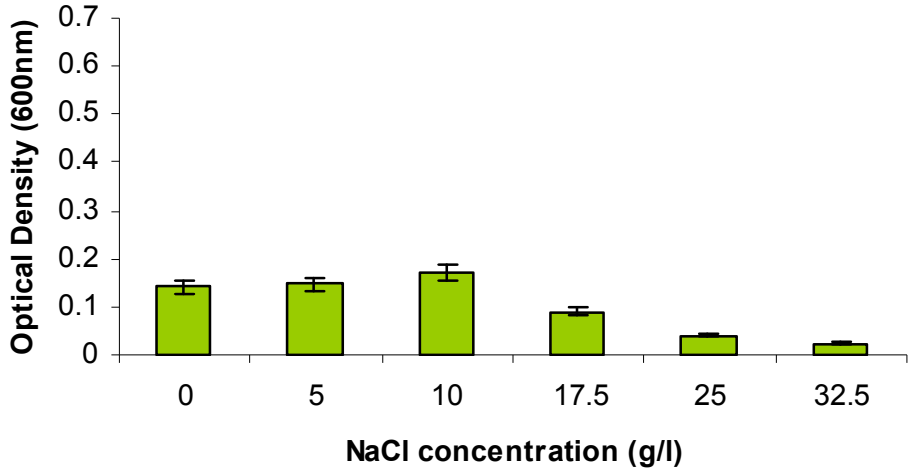


Figure 4c: Growth of isolate Chy 15-5 under different sodium chloride concentrations (P<0.05)

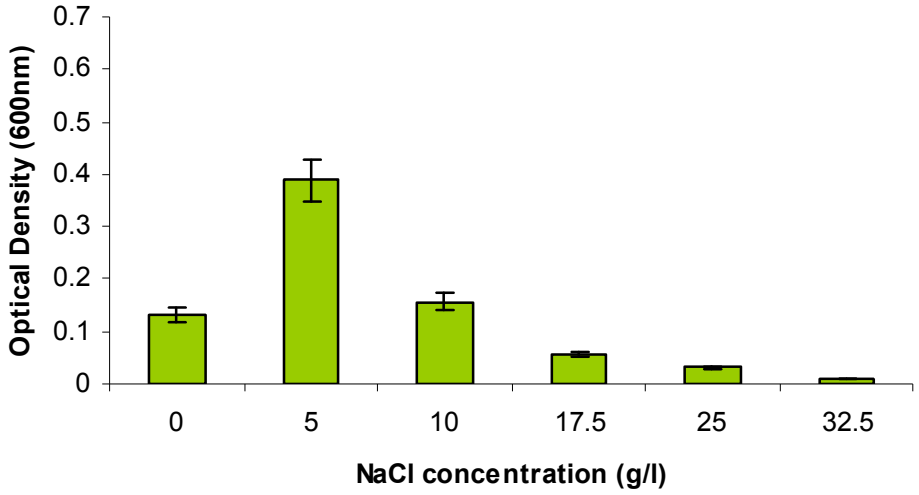


Figure 4d: Growth of isolate Chy 2-3 under different sodium chloride concentrations (P<0.05).

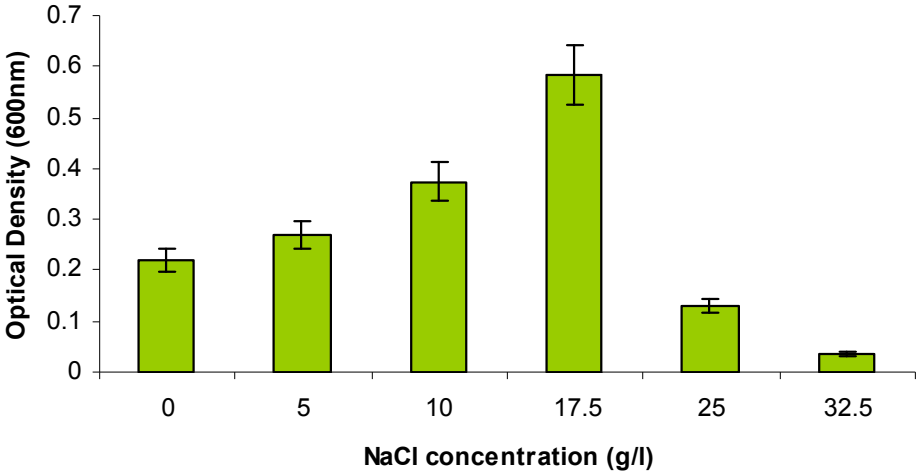


Figure 4e: Growth of isolate Ruj 7-1 under different sodium chloride concentrations (P<0.05).

3.2 Extraction and Activity of Secondary Metabolites

Production of secondary metabolites by the isolates was observed in differential broth cultures by a change in colour of the media from colorless to; red (Chy 4-10), dark brown (Chy 15-10), light brown (Chy 15-5), Orange (Chy 2-3) and black (Ruj 7-1) (Figure 5a – 5e).

The isolates were tested for inhibition of growth on test organisms *S. aureus* (NCTC 10788) and *E. coli* (NCTC 10418) (Table 3). Isolates Chy 4-10, Chy 15-5 and Ruj 7-1 were found to suppress the growth of the two test bacteria while isolates Chy 15-10 and Chy 2-3 only suppressed growth of *S. aureus* (NCTC 10788) (Table 3). Isolate Chy 4-10 (24mm) and Chy 2-3 (20mm) showed stronger inhibition on *S. aureus* (NCTC 10788) while isolates Chy 15-5 (18mm) and Ruj 7-1 (15mm) showed stronger inhibition on *E. coli* (NCTC 10418) (Table 3). Isolates Chy 4-10, Chy 15-5 and Ruj 7-1 showed strong inhibition on both test organisms hence broad-spectrum activity (Table 3). This showed the potential of the isolates to produce antibiotics. The positive control consisted of commercial Kanamycin antibiotic (1mg/ml) while negative control consisted of un-innoculated plate.

Yields of the secondary metabolites produced were determined as shown in (Table 3). Isolate CHY15-10 produced the highest yield (0.62g/l) whereas RUJ7-1 produced the least (0.14g/l).

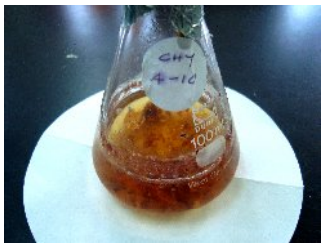


Figure 5a: Broth culture showing production of secondary metabolites by isolate CHY4-10.

Figure 5b: Broth culture showing production of secondary metabolites by isolate CHY15-10.

Figure 5c: Broth culture showing

Figure 5d: Broth culture showing production of secondary metabolites by isolate CHY2-3.

Table 3: Bio-assays of secondary metabolites crude extracts from the Streptomyces isolates on S. aureus (NCTC 10788) and E. coli (NCTC 10418)

Isolate	**Activity**		**Disc assay (diameter in mm)**		Yield (g/l)
	S. aureus (NCTC 10788)	*E. coli* (NCTC 10418)	*S. aureus* (NCTC 10788)	*E. coli* (NCTC 10418)	
Chy 4-10	+	+	24	9	0.54
Chy 15-10	+	-	13	-	0.62
Chy 15-5	+	+	15	18	0.41
Chy 2-3	+	-	20	-	0.3
Ruj 7-1	+	+	19	15	0.14
+ve control	+	+	15	19	
-ve control	-	-	0	0	

* Zones of inhibition measured in mm.
+ = Inhibition
- = No inhibition.

3.3 GC-MS Analysis Of Crude Extracts From The Actinobacteria Isolates

Mass spectra and retention time analysis were used to determine the chemical compounds present in the respective isolate metabolites. Among the compounds identified comprised of amides, amines, acids, pyrrolizidines, quinones, alcohols and hydrocarbons. Amides identified from isolate Chy 4-10 were: Propanamide, N, N-dimethyl- (17.667 min), Acetamide,2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)- (23.715min) and Formamide, N-(2,4-diamino-1,6-dihydro-6-oxo-5-pyrimidinyl)- (29.000min). Amines comprised of: Pyrimidine, 2-methoxy-5-methyl- (18.698 min), Pyridine, 2-methoxy-5-nitro- (22.057 min), Pyrimidine-2(1H)-thione, 4,4,6-trimethyl-1-(1-phenylethyl)- (29.023 min) and l-Phenylalanine, N-(2,6-difluorobenzoyl)-, methyl ester (29.291 min). Acids: Benzenepropanoic acid (16.391min), Sulfurous acid, 2-ethylhexyl hexyl ester (17.063 min), 2-Hexenoic acid, 5-hydroxy-3,4,4-trimethyl-, (E)- (21.408 min), 1,2-Benzenedicarboxylic acid, butyl 2-methylpropyl ester (23.468 min), n-Hexadecanoic acid (23.468 min), Phosphonic acid, bis(1-methylethyl) ester (24.028 min), Octadecanoic acid (25.327 min) and 1-Phenanthrenecarboxylic acid, 7-ethenyl-1,2,3,4,4a,4b,5,6,7,8,10,10a-dodeca hydro-1,4a,7-trimethyl-, methyl ester, [1R-(1.alpha.,4a. (27.813 min). Pyrrolizidines: Pyrrolo[1,2-a]pyrazine-1,4-dione, hexahydro- (21.587 min) and Pyrrolo[1,2-a]pyrazine-1,4-dione, hexahydro-3-(phenylmethyl)- (26.940 min). Quinone: p-Benzoquinone, 2-hydroxy-5-(methylthio)- (25.932 min). Alcohols: Propenylguaethol (17.175 min), Phenol, 3-methoxy- (17.555 min) and Phenol, 3, 5-dimethoxy- (22.416 min). Hydrocarbons: Tridecane, 1-iodo- (20.669 min), Tridecane, 5-propyl- (20.736 min), 7-Acetyl-1,7-diazabicyclo[2.2.0]heptane (21.206 min), Heneicosane (21.744 min), Nonadecane (22.774 min), 1,4-Dioxaspiro[4.5]decane, 6-methylene- (23.222 min), Heptadecane (24.678 min), Hexacosane (28.821 min), Triacontane (29.560 min), Nonacosane (31.240 min), and Tetracosane (33.592 min). Other chemical compounds identified were: Caprolactam (15.248 min) and Squalene (30.658 min) (Table 4).

Table 4: Compounds identified from isolate CHY 4-10

Retention Time (min)	Compound Name	% of total	Quality
6.648	2-Pentanone, 4-hydroxy-	0.275	83
10.187	Ethanone, 1-(2-methyl-1-cyclopenten-1-yl)-	0.717	72
12.001	2-Pentene, 4,4-dimethyl-, (Z)-	1.618	79
14.151	2-Piperidinone	1.003	72
15.248	Caprolactam	1.610	74
15.808	5-Methoxy-2,4-dimethyl-furan-3-one	12.237	70
16.391	Benzenepropanoic acid	0.763	90
17.063	Sulfurous acid, 2-ethylhexyl hexyl ester	0.334	72
17.175	Propenylguaethol	0.230	75
17.555	Phenol, 3-methoxy-	0.690	70
17.667	Propanamide, N,N-dimethyl-	0.362	73
18.698	Pyrimidine, 2-methoxy-5-methyl-	0.855	70
19.213	4-Methylformanilide	0.325	77
19.526	Borane, diethyl(decyloxy)-	0.230	72
19.952	Benzene, 3,5-dimethyl-1-(phenylmethyl)-	0.658	91
20.512	2,6-Diisopropylnaphthalene	0.290	91
20.669	Tridecane, 1-iodo-	0.188	70
20.736	Tridecane, 5-propyl-	0.309	77
20.937	(Z)-2-Methylimino-4,5-tetramethylenetetrahydro-1,3-oxazine	0.320	75
21.206	7-Acetyl-1,7-diazabicyclo[2.2.0]heptane	0.560	72
21.408	2-Hexenoic acid, 5-hydroxy-3,4,4-trimethyl-, (E)-	0.589	75
21.587	Pyrrolo[1,2-a]pyrazine-1,4-dione, hexahydro-	1.761	86

21.744	Heneicosane	1.230	86
22.057	Pyridine, 2-methoxy-5-nitro-	0.236	72
22.416	Phenol, 3,5-dimethoxy-	0.560	83
22.528	Phthalic acid, isobutyl nonyl ester	0.616	83
22.774	Nonadecane	0.400	90
23.065	7,9-Di-tert-butyl-1-oxaspiro(4,5)deca-6,9-diene-2,8-dione	0.890	99
23.222	1,4-Dioxaspiro[4.5]decane, 6-methylene-	1.002	72
23.468	1,2-Benzenedicarboxylic acid, butyl 2-methylpropyl ester	1.560	78
23.513	n-Hexadecanoic acid	0.560	94
23.715	Acetamide, 2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)-	2.260	83
24.028	Phosphonic acid, bis(1-methylethyl) ester	0.966	83
24.364	1,4-Anthracenedione, 5,6,7,8-tetrahydro-2-methoxy-5,5-dimethyl-	0.484	89
24.678	Heptadecane	0.656	83
25.327	Octadecanoic acid	3.307	99
25.932	p-Benzoquinone, 2-hydroxy-5-(methylthio)-	9.493	78
26.940	Pyrrolo[1,2-a]pyrazine-1,4-dione, hexahydro-3-(phenylmethyl)-	1.992	90
27.477	1-Phenanthrenecarboxylic acid, 7-ethenyl-1,2,3,4,4a,4b,5,6,7,8,10,10a-dodeca hydro-1,4a,7-trimethyl-, methyl ester, [1R-(1.alpha.,4a.	0.651	73
27.813	1-Phenanthrenecarboxylic acid, 1,2,3,4,4a,9,10,10a-octahydro-1,4a-dimethyl-7 -(1-methylethyl)-, [1R-(1.alpha.,4a.beta.,10a.alpha.)]-	0.923	94

28.485	Phthalic acid, 6-ethyloct-3-yl 2-ethylhexyl ester		83
28.821	Hexacosane	0.368	90
29.000	Formamide, N-(2,4-diamino-1,6-dihydro-6-oxo-5-pyrimidinyl)-	1.960	72
29.023	Pyrimidine-2(1H)-thione, 4,4,6-trimethyl-1-(1-phenylethyl)-	1.230	82
29.291	l-Phenylalanine, N-(2,6-difluorobenzoyl)-, methyl ester	1.600	78
29.560	Triacontane	0.676	91
30.344	Heptadecane	0.604	91
30.658	Squalene	0.369	93
31.240	Nonacosane	0.599	96
32.315	Triacontane	0.314	94
33.592	Tetracosane	0.246	83
36.817	Heptamethyl-3-phenyl-1,4-cyclohexadiene	0.796	77

Chemical compounds identified from isolate Ruj 7-1 included: Amide: Acetamide, 2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)- (23.715 min). Alcohols: 1, 4-Dioxane-2, 6-dimethanol (15.584 min), 1-Tridecanol (22.707 min) and Phenol, 4, 4'-(1-methylethylidene) bis [2, 6-dichloro- (29.359 min). Acids: Dodecanoic acid (19.101 min), Tetradecanoic acid (21.340 min), Diethyldithiophosphinic acid (22.236 min), Octadecanoic acid (25.260 min), 1,2-Benzenedicarboxylic acid, mono(2-ethylhexyl) ester (28.485 min) and Oxalic acid, monoamide, monohydrazide, N-(2,5-dimethylphenyl)-N2-(4-methylbenzylideno)- (29.919 min). Hydrocarbons: Hexadecane (19.526 min), Heptadecane (27.253 min), Octadecane (28.060 min), Hexacosane (28.821 min), Heptacosane (29.560 min), Octadecane, 1-iodo- (30.031 min), Octacosane (30.882 min), Tetracosane (31.240 min), Nonacosane (31.890 min) and Triacontane (32.315 min) (Table 5).

Table 5: Compounds identified from isolate RUJ7-1

Retention Time (min)	**Compound Name**	**% of total**	**Quality**
9.156	2-Butenal, 3-methyl-	0.360	73
15.584	1,4-Dioxane-2,6-dimethanol	18.055	78

18.071	1,1'-Bicyclohexyl, 2-methyl-, trans-	0.630	71
19.101	Dodecanoic acid	1.077	95
19.302	Naphthalene, 1,6-dimethyl-	0.890	58
19.526	Hexadecane	0.456	97
21.340	Tetradecanoic acid	2.988	95
22.236	Diethyldithiophosphinic acid	0.690	78
22.505	Phthalic acid, isobutyl octyl ester	1.181	90
22.707	1-Tridecanol	0.919	91
23.065	2,5-Cyclohexadien-1-one, 2,6-bis(1,1-dimethylethyl)-4-ethylidene-	6.090	70
23.446	Dibutyl phthalate	27.546	94
23.715	Acetamide, 2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)-	2.175	98
25.260	Octadecanoic acid	3.804	99
26.940	4,8,12,16-Tetramethylheptadecan-4-olide	0.804	95
27.253	Heptadecane	1.389	97
28.060	Octadecane	1.580	97
28.485	1,2-Benzenedicarboxylic acid, mono(2-ethylhexyl) ester	2.297	91
28.821	Hexacosane	1.615	98
29.359	Phenol, 4,4'-(1-methylethylidene)bis[2,6-dichloro-	0.990	93
29.560	Heptacosane	1.954	98
29.919	Oxalic acid, monoamide, monohydrazide, N-(2,5-dimethylphenyl)-N2-(4-methylbe nzylideno)-	0.980	93
30.031	Octadecane, 1-iodo-	1.009	93
30.658	Squalene	2.283	97
30.882	Octacosane	1.008	90

31.240	Tetracosane	1.023	97
31.890	Nonacosane		96
32.315	Triacontane	1.003	99

Chemical compounds identified from isolate Chy 2-3 included: Amides: Propanamide, 2-methyl- (9.694 min), N-Methoxymethyl-N-methylformamide (11.015 min), L-Prolinamide (21.072 min), Acetamide, 2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)- (23.737 min) and Formamide, N-(2,4-diamino-1,6-dihydro-6-oxo-5-pyrimidinyl)- 29.157 min). Amines: 2-Ethylpiperidine (12.830 min) and Pyrimidine-2(1H)-thione, 4,4,6-trimethyl-1-(1-phenylethyl)- (29.381 min). Acids: Acetic acid, 2-methylpropyl ester (5.416 min), 2-Propenoic acid, 2-methyl- (8.709 min), Hexanoic acid, 2-methyl- (9.044 min), Pentanoic acid (9.515 min), Benzeneacetic acid (15.450 min), Benzenepropanoic acid (16.480 min), 5-Oxohexanethioic acid, S-t-butyl ester (17.802 min), Dodecanoic acid (19.146 min), n-Hexadecanoic acid (23.535 min), Octadecanoic acid (25.327 min), p-Fluorophenoxyacetic acid (25.574 min), 1,2-Benzenedicarboxylic acid, mono(2-ethylhexyl) ester (28.508 min) and Octadecanoic acid, ethenyl ester (41.700 min). Alcohols: 1,2-Ethanediol, monoacetate (7.678 min), p-Dioxane-2,5-dimethanol (16.032 min), Cyclohexanol, 4-methoxy- (18.272 min) and Phenol, 3,5-dimethoxy- (22.528 min). Ketones: 2-Pyrrolidinone (12.449 min), 2, 5-Piperazinedione, 3, 6-bis (2-methylpropyl) - (25.910 min) and 16-Hentriacontanone (36.795 min). Hydrocarbons: Cyclohexane (13.681 min), Tetradecane (17.063), Hexadecane (19.526 min), Hexacosane (28.821 min) and Tetracosane (30.344 min). Pyrrolizidines: Pyrrolo[1,2-a]pyrazine-1,4-dione, hexahydro- (21.766 min) and Pyrrolo[1,2-a]pyrazine-1,4-dione, hexahydro-3-(phenylmethyl (26.985 min). Caprolactam was also detected at (15.808 min) retention time (Table 6).

Table 6: Compounds identified from isolate CHY2-3

Retention Time (min)	**Compound Name**	**% of total**	**% Quality**
5.416	Acetic acid, 2-methylpropyl ester	0.073	83
7.678	1,2-Ethanediol, monoacetate	0.397	78
8.709	2-Propenoic acid, 2-methyl-	1.742	70
9.044	Hexanoic acid, 2-methyl-	0.960	72
9.515	Pentanoic acid	0.662	83
9.694	Propanamide, 2-methyl-	0.630	80
11.015	N-Methoxymethyl-N-methylformamide	0.313	78
12.449	2-Pyrrolidinone	0.520	89
12.516	Furan, tetrahydro-2,5-dipropyl-	0.072	75
12.830	2-Ethylpiperidine	0.230	86
13.681	Cyclohexane	0.500	72

14.778	Thiophene, 2,3-dihydro-	2.319	86
15.450	Benzeneacetic acid	1.319	76
15.808	Caprolactam	1.419	83
16.032	p-Dioxane-2,5-dimethanol	0.566	76
16.480	Benzenepropanoic acid	0.0103	97
17.063	Tetradecane	0.332	98
17.802	5-Oxohexanethioic acid, S-t-butyl ester	0.822	75
18.272	Cyclohexanol, 4-methoxy-	0.890	75
18.630	4-Ethyl hydrogen itaconate	0.385	72
19.146	Dodecanoic acid	0.900	99
19.526	Hexadecane	0.860	96
20.579	2,6-Diisopropylnaphthalene	0.369	93
21.072	L-Prolinamide	0.290	77
21.363	3-Pyrrolidin-2-yl-propionic acid	2.133	86
21.766	Pyrrolo[1,2-a]pyrazine-1,4-dione, hexahydro-	2.710	83
22.528	Phenol, 3,5-dimethoxy-	2.890	83
22.953	Bicyclo[3.1.0]hex-2-ene, 5,6-diphenyl-	1.900	72
23.088	7,9-Di-tert-butyl-1-oxaspiro(4,5)deca-6,9-diene-2,8-dione	1.256	99
23.311	5,10-Diethoxy-2,3,7,8-tetrahydro-1H,6H-dipyrrolo[1,2-a;1',2'-d]pyrazine	1.230	79
23.535	n-Hexadecanoic acid	1.036	98
23.737	Acetamide, 2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)-	1.089	78
25.327	Octadecanoic acid	2.364	99
25.574	p-Fluorophenoxyacetic acid	1.357	82
25.910	2,5-Piperazinedione, 3,6-bis(2-methylpropyl)-	13.999	72

26.581	Benzene, 1-ethyl-4-(1-methylethyl)-	1.230	75
26.985	Pyrrolo[1,2-a]pyrazine-1,4-dione, hexahydro-3-(phenylmethyl)-	1.520	93
28.508	1,2-Benzenedicarboxylic acid, mono(2-ethylhexyl) ester	0.980	91
28.821	Hexacosane	0.900	95
29.157	Formamide, N-(2,4-diamino-1,6-dihydro-6-oxo-5-pyrimidinyl)-	2.530	78
29.381	Pyrimidine-2(1H)-thione, 4,4,6-trimethyl-1-(1-phenylethyl)-	1.710	77
30.344	Tetracosane	0.254	97
36.795	16-Hentriacontanone	0.301	78
41.700	Octadecanoic acid, ethenyl ester	0.532	88

Secondary metabolites from Chy 15-5 analyzed had the following chemical compounds, Amide: Acetamide, 2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)- (23.715 min). Acids: Hexanoic acid (10.814 min), Heptanoic acid (12.426 min), Cyclohexanecarboxylic acid (13.165 min), Benzenecarboxylic acid (14.263 min), Nonanoic acid (15.428 min), n-Decanoic acid (16.659 min), Dodecanoic acid (19.123 min), Tetradecanoic acid (21.363 min), Pentadecanoic acid (22.393 min), n-Hexadecanoic acid (23.558 min), 9-Octadecenoic acid, (E)- (25.081 min), Octadecanoic acid (25.372 min), 1-Phenanthrenecarboxylic acid, 1,2,3,4,4a,9,10,10a-octahydro-1,4a-dimethyl-7-(1-methylethyl)-,[1R (1.alpha.,4a.beta.,10a.alpha.)]-(27.791min),Hexadecane acid, 4-nitrophenyl ester (36.817 min) and Octadecanoic acid, ethenyl ester (41.744 min). Ketone: 2-Pentadecanone, 6, 10, 14-trimethyl- (22.236 min). Hydrocarbons: Tetradecane (17.085 min), Pentadecane (18.339 min), Hexadecane (19.526 min), Pentadecane, 2,6,10,14-tetramethyl- (20.736 min), Hexadecane, 2,6,10,14-tetramethyl- (21.856 min), Nonadecane (22.774 min), Heneicosane (24.700 min), Docosane (25.596 min), Octadecane (26.447 min), Eicosane (28.821 min), Tricosane (29.583 min), Squalene (30.658 min), Nonacosane (31.262 min), Tetracosane (32.315 min) and Octacosane (33.592 min) (Table 7).

Table 7: Compounds identified from isolate CHY15-5

Retention Time (min)	**Compound Name**	**% of total**	**% Quality**
10.814	Hexanoic acid	0.590	83
12.426	Heptanoic acid	0.003	79
13.165	Cyclohexanecarboxylic acid	0.360	97
14.263	Benzenecarboxylic acid	0.895	93
15.248	Caprolactam	2.010	91

15.428	Nonanoic acid	0.532	93
16.010	Phthalic anhydride	0.870	81
16.659	n-Decanoic acid	0.191	98
17.085	Tetradecane	0.348	97
17.152	Vanillin	0.850	97
18.048	alpha-Cedrene oxide	0.197	76
18.339	Pentadecane	0.600	97
18.586	Tributyl phosphate	0.185	73
19.123	Dodecanoic acid	0.680	99
19.526	Hexadecane	0.603	98
19.862	Dodecanoic acid, 1-methylethyl ester	0.166	90
20.310	1,1'-Biphenyl, 4-(1-methylethyl)-	0.585	96
20.512	2,6-Diisopropylnaphthalene	1.370	95
20.736	Pentadecane, 2,6,10,14-tetramethyl-	0.330	94
20.893	2-(p-Tolylmethyl)-p-xylene	0.590	78
21.363	Tetradecanoic acid	1.867	99
21.856	Hexadecane, 2,6,10,14-tetramethyl-	0.629	95
22.236	2-Pentadecanone, 6,10,14-trimethyl-	0.780	89
22.393	Pentadecanoic acid	0.623	99
22.528	1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	1.530	73
22.774	Nonadecane	1.411	80
22.931	Benzene, (1-methyldodecyl)-	1.980	76
23.087	2,5-Cyclohexadien-1-one, 2,6-bis(1,1-dimethylethyl)-4-ethylidene-	1.862	86
23.558	n-Hexadecanoic acid	6.182	98
23.715	Acetamide, 2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-	3.010	73

	methoxy-1-methylethyl)-		
24.364	Heptadecanoic acid	2.270	91
24.700	Heneicosane	1.312	98
25.081	9-Octadecenoic acid, (E)-	3.361	99
25.372	Octadecanoic acid	11.471	99
25.596	Docosane	3.260	99
26.447	Octadecane	1.911	97
27.477	Androst-5-en-17-ol, 4,4-dimethyl-	1.903	75
27.791	1-Phenanthrenecarboxylic acid, 1,2,3,4,4a,9,10,10a-octahydro-1,4a-dimethyl-7 -(1-methylethyl)-, [1R-(1.alpha.,4a.beta.,10a.alpha.)]-	2.650	99
28.485	Phthalic acid, decyl 2-ethylhexyl ester	2.224	72
28.821	Eicosane	1.570	98
29.583	Tricosane	1.346	98
30.658	Squalene	1.416	98
31.262	Nonacosane	1.723	99
32.315	Tetracosane	0.887	97
33.592	Octacosane	0.804	98
36.817	Hexadecanoic acid, 4-nitrophenyl ester	0.367	78
37.959	Stigmastanol	0.467	78
41.744	Octadecanoic acid, ethenyl ester	4.108	83

Isolate CHY15-10 produced secondary metabolites with the following chemical compounds, Amides: L-Prolinamide (20.982 min) and N-(4-Methoxyphenyl)-2-hydroxyimino-acetamide (23.289 min). Amines: Pyrimidine-2(1H)-thione, 4, 4, 6-trimethyl-1-(1-phenylethyl) - (29.336 min). Acids: Butanoic acid, 3-methyl- (8.395 min), Butanoic acid, 2-methyl- (8.619 min), Benzenecarboxylic acid (14.420 min), Benzeneacetic acid (15.338 min), Benzenepropanoic acid (16.413 min), Dodecanoic acid (19.146 min), n-Hexadecanoic acid (23.535 min), Heptadecanoic acid 924.364 min), 9-Octadecenoic acid, (E)- (25.081 min), Octadecanoic acid (25.350 min), 1,2- Benzenedicarboxylic acid, mono(2-ethylhexyl) ester (28.463 min) and Hexadecanedioic acid (29.717 min). Hydrocarbons: Tetradecane (17.085), Hexadecane (19.526 min), Nonadecane (22.774 min), Tridecane (23.759 min), Heneicosane (26.447 min), Tetracosane (27.276 min), Pentacosane (28.060 min), Octacosane (29.538 min),

Triacontane (30.344 min), Squalene (30.658 min), Nonacosane (31.240 min), Heptadecane, 9-octyl- (32.024 min) and Heptadecane (32.315 min). Alcohols: 1,4-Dioxane-2,6-dimethanol (15.719 min) and Phenol, 3,5-dimethoxy- (22.460 min). Pyrrolizidines: Pyrrolo[1,2-a]pyrazine-1,4-dione, hexahydro- (21.744 min) (Table 8).

Table 8: Compounds identified from isolate CHY15-10

Retention Time (min)	**Compound Name**	**% of total**	**% Quality**
7.633	1,2-Ethanediol, monoacetate	0.230	74
8.395	Butanoic acid, 3-methyl-	0.560	83
8.619	Butanoic acid, 2-methyl-	0.123	74
9.224	Dimethyl sulfone	0.269	85
14.196	2-Piperidinone	1.481	86
14.420	Benzenecarboxylic acid	0.560	95
14.845	1H-Pyrrole-2-carboxylic acid	0.234	91
15.338	Benzeneacetic acid	3.036	64
15.540	Caprolactam	0.589	76
15.719	1,4-Dioxane-2,6-dimethanol	1.002	89
16.413	Benzenepropanoic acid	1.117	97
17.085	Tetradecane	1.230	97
17.17	Vanillin	0.840	93
19.146	Dodecanoic acid	0.980	99
19.526	Hexadecane	0.589	97
20.579	2,6-Diisopropylnaphthalene	0.258	95
20.982	L-Prolinamide	0.789	77
21.273	3,7-Dimethyloctyl acetate	3.088	78
21.744	Pyrrolo[1,2-a]pyrazine-1,4-dione, hexahydro-	12.539	96
22.460	Phenol, 3,5-dimethoxy-	3.409	77
22.528	1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	0.968	94

22.774	Nonadecane	0.879	98
23.087	2,5-Cyclohexadien-1-one, 2,6-bis(1,1-dimethylethyl)-4-ethylidene-	1.125	79
23.289	N-(4-Methoxyphenyl)-2-hydroxyimino-acetamide	0.456	91
23.535	n-Hexadecanoic acid	11.074	98
23.759	Tridecane	2.067	94
24.364	Heptadecanoic acid	1.456	95
25.081	9-Octadecenoic acid, (E)-	1.790	97
25.350	Octadecanoic acid	5.746	99
26.044	cis-2-Thioxo-5,6-trimethylene-2,3,5,6-tetrahydropyrimidin-4(1H)-one	26.891	77
26.447	Heneicosane	2.369	98
26.962	1-Phenanthrenecarboxylic acid, 1,2,3,4,4a,9,10,10a-octahydro-1,4a-dimethyl-7 -(1-methylethyl)-, methyl ester, [1R-(1.alpha.,4a.beta.,	1.386	75
27.276	Tetracosane	0.646	99
27.477	1-Phenanthrenecarboxylic acid, 7-ethenyl-1,2,3,4,4a,4b,5,6,7,8,10,10a-dodeca hydro-1,4a,7-trimethyl-, methyl ester, [1R-(1.alpha.,4a.	0.890	86
27.791	1-Phenanthrenecarboxylic acid, 1,2,3,4,4a,9,10,10a-octahydro-1,4a-dimethyl-7 -(1-methylethyl)-, [1R-(1.alpha.,4a.beta.,10a.alpha.)]-	0.789	99
28.060	Pentacosane	0.855	98
28.463	1,2-Benzenedicarboxylic acid, mono(2-ethylhexyl) ester	3.480	87
29.336	Pyrimidine-2(1H)-thione, 4,4,6-trimethyl-1-(1-phenylethyl)-	1.470	78
29.538	Octacosane	0.929	96
29.717	Hexadecanedioic acid	0.456	74
30.344	Triacontane	0.976	98
30.658	Squalene	1.009	91

31.240	Nonacosane	1.467	98
32.024	Heptadecane, 9-octyl-	0.870	93
32.315	Heptadecane	0.892	96

4.0 Discussion

The isolates had been isolated from two Kenyan National Parks namely Chyulu and Ruma National parks. Differential media was used to revive the isolates. The medium had fermentable carbohydrate, nitrogen, organic and inorganic compounds. Morphological studies were carried out and characteristics of the isolates compared with the standard characteristics described in Bergy's manual. They formed colored, tough and leathery colonies that were hard to pick from the culture media. Microscopic studies also showed that the isolates cells formed long branched network of mycelia a characteristic of *Streptomyces sp* as previously described by Kieser *et al.,* (2000).

Physiochemical characterization of the isolates Chy 4-10, Chy 15-10, Chy 15-5 and Chy 2-3 on pH showed optimal growth of the isolates at pH range of 6 - 9. These results were in accordance to Gava (1998) who reported that majority of Actinomycetes isolated from rhizosphere and non-rhizosphere soil grows at a pH range varying from 6.5 to 8.0. Isolate Ruj 7-1 yielded good growth, characterized by abundant mycelium, in culture media with pH 6.0 suggesting its tolerance to acidic condition. The optimum pH level allows for optimal metabolic reactions characterized by enzymes hence the increase in growth of microorganisms (Moreira & Siqueira, 2002). Isolates CHY4-10, CHY15-10, CHY15-5, CHY2-3 and RUJ7-1 showed optimum growth at 30 °C, 32.5 °C, 30 °C, 32.5 °C and 27.5 °C respectively. Minimal growth was recorded below 27.5 °C and above 32.5 °C. These results also confirmed that isolates Chy 4-10, Chy 15-10, Chy 15-5 and Chy 2-3 originated from a relatively warmer ecosystem than isolate Ruj 7-1 (27.5 °C). According to Goodfellow *et al.* (1990), bacterial growth rates increase with temperature up to the optimum temperature, at which the growth rate is maximal. Enzymatic processes are thought to limit further increases in growth rates at temperatures above the optimum temperature (Goodfellow *et al.,* 1990).

Growth of the isolates in culture medium with varying NaCl levels (0 g/l to 32.5 g/l) confirmed tolerance to saline conditions. All the isolates recorded growth in absence of sodium chloride but isolate Chy 4-10, Chy 15-10 and Chy 2-3 indicated an increase in growth at 5 g/l sodium chloride concentration which was similar to that of *Nocardiopsis kunsanensis* sp. nov., a moderately halophilic actinomycete (Chun *et al.,* 2000). Isolate Chy 15-5 and Ruj 7-1 grew optimally at higher NaCl concentrations (10 g/l and 17.5 g/l) respectively meaning they were more tolerant and also required higher NaCl concentrations for them to grow.

Most microorganisms obtain their energy through a series of orderly and integrated enzymatic reactions leading to the biooxidation of a substrate that is frequently a carbohydrate. The organisms use the carbohydrate differently depending on their enzyme complement. Some organisms ferment sugars such as glucose anaerobically, while others use the aerobic pathway (Williams *et al*., 1989). Glucose was the best carbon source for growth of isolates Chy 4-10 (0.601nm), Chy 15-5 (0.719nm) and Chy 2-3 (0.475nm). This meant that glucose would give optimum growth during fermentation processes than the other sugars. Sucrose also indicated a considerable growth of the isolate Chy 4-10 (0.473nm) meaning it could act as an alternative source of carbon for this isolate. Mannose would also be an alternative source of carbon to isolate Chy 15-5 (0.250nm) besides glucose. Xylose was the preferred carbon source for isolates Chy 15-10 (0.899nm) and Ruj 7-1 (0.900nm) hence it would be the ideal carbon source during fermentation processes of isolates.

Actinomycetes are a prolific source of secondary metabolites. Around 23,000 bioactive secondary metabolites produced by microorganisms have been reported and over 10,000 of these compounds are produced by Actinomycetes, representing 45% of all bioactive microbial metabolites discovered (Berdy, 2005). Among Actinomycetes, around 7,600 compounds are produced by *Streptomyces* species (Berdy, 2005). Streptomyces species are distributed widely in aquatic and terrestrial habitats Pathom-aree *et al.* (2006) and are of commercial interest due to their unique capacity to produce novel bioactive compounds. The main source for the bioactive secondary metabolites is soil streptomycetes, but a wide variety of structurally unique and biologically active secondary metabolites have recently been isolated from marine Actinomycetes, including those from the genus *Streptomyces* (Cho *et al.,* 2001; Sanchez-Lopez *et al.,* 2003; Lee *et al.,* 2005; Jensen *et al.,* 2005).

Production of secondary metabolites commonly precedes the development of aerial hyphae, when the growth rate of bacterial filaments has decreased and sporulation starts (Bibb, 2005). Much of the published data indicate that the most important environmental signal triggering secondary metabolism is nutrient starvation, particularly that of phosphate (Sola-Landa *et al.,* 2003). The signaling networks behind the regulation of secondary metabolism in streptomycetes have recently been reviewed (Bibb, 2005). Many of these secondary metabolites are potent antibiotics, which has made streptomycetes the primary antibiotic-producing organisms exploited by the pharmaceutical industry (Berdy, 2005).

Besides antibiotics, which present the largest group of bioactive secondary metabolites, these antimicrobial compounds show several other biological activities i.e. antagonistic agents**,** including antibacterials, antifungals, antiprotozoans as well as antivirals, pharmacological agents, including antitumorals, immunomodulators, neurological agents and enzyme inhibitors, agrobiologicals, including insecticides, pesticides and herbicides, and compounds with regulatory activities, such as growth factors, siderophores or morphogenic agents. To detect simultaneous bioactivities for a given compound, pharmacological and agricultural screens are increasingly being used in combination with antimicrobial tests. This has revealed several novel therapeutic and agrobiological agents and previously unknown biological activities for antibiotics (Berdy, 1995; Sanglier *et al.,* 1996; Berdy, 2005).

Progress has been made recently on drug discovery from Actinomycetes by using high- throughput screening and fermentation, mining genomes for cryptic pathways, and combinatorial biosynthesis to generate new secondary metabolites related to existing pharmacophores (Baltz, 2008).

In this research, five Actinobacteria isolates were studied for the production of secondary metabolites. Yields of the secondary metabolites produced were determined and isolate CHY 15-10 produced the highest yield (0.62 g/l) whereas RUJ 7-1 produced the least (0.14 g/l). The five isolates were also tested for their *in vitro* activity on type culture collection of gram-positive (*S. aureus* NCTC 10788) and gram-negative bacteria (*E. coli* NCTC 10418). All the isolates had inhibitory effects on *S. aureus* but with different levels of inhibition. Isolate Chy 4-10 showed stronger inhibition against *S. aureus* NCTC 10788 with an inhibition diameter of 24mm followed by isolate Chy 2-3 (20mm) whereas isolate Chy 15-10 recorded the weakest inhibition of 13mm. The results were an indication that although all the isolates showed activity on the test microorganism, the degree of activity was varying due to the different or varying concentrations of the active ingredient. On the Gram negative *E. coli* NCTC 10418, isolates Chy 15-10 and Chy 2-3 showed no antagonistic effect on the test organism. However, isolate Chy 15-5 and Ruj 7-1 showed inhibitory effects on the test organism with zones of inhibition measuring 18mm and 15mm indicating higher chances of producing secondary metabolites that would counteract growth of Gram negative bacteria.

GC-MS analysis of the secondary metabolites was carried out and profiles of the fractions indicated the presence of different number of chemical compounds with different retention times and abundance. Among the compounds identified comprised of amides, amines, acids, pyrrolizidines, ketones, quinones, alcohols and hydrocarbons. Some of these compounds have been detected from Actinobacteria and documented. Quinone related compounds with antitumor activity have been isolated from different marine Actinomycetes. *Streptomyces chinaensis* AUBN1/7 isolated from marine sediment samples of Bay of Bengal, India, is the producer of 1-hydroxy-1-norresistomycin and resistoflavin (Gorajana *et al.,* 2005). These compounds together with resistomycin and tetracenomycin D have also been produced by *Streptomyces* sp. B8005 isolated from sediments of the Laguna de Términos at the Gulf of México (Kock *et al.,* 2005). Resistomycin was isolated, in addition, from *Streptomyces* sp. B4842 from mud sediment of a coastal site of Mauritius, Indian Ocean (Kock *et al.,* 2005). 1-hydroxy-1-norresistomycin (Gorajana *et al.,* 2005) and resistoflavin (Gorajana *et al.,* 2007) showed cytotoxic activity against human gastric adenocarcinoma HMO2 and hepatic carcinoma HePG2 cell lines. Apart from the common or documented quinones obtained from *Streptomyces*, a unique group of quinone compound was detected from isolate Chy 4-10 in this study. p-Benzoquinone2-hydroxy-5-(methylthio)- from isolate Chy 4-10 was detected at 25.932 min retention time with an abundance of 9.493%. The potential of this compound as an antitumor is still not known.

Two new cytotoxic quinones of the angucycline class, marmycins A and B have been isolated from the culture broth of *Streptomyces* strain CNH990 isolated from a sediment sample collected at a depth of 20 m at the entrance to the Sea of Cortez, 5 km east of Cabo San Lucas, México (Martin *et al.,* 2007). In cytotoxic assays using the human cell line of colon adenocarcinoma HCT-116, marmycin A showed an IC50 of 60.5 nM, almost 18 times more potent than marmycin B, which showed an IC50 of 1.09 µM. Marmycin A was further evaluated for its *in vitro* cytotoxicity showing a mean IC50 value of 0.022 µM against 12 human tumor cell lines (breast, prostate, colon, lung, leukemia). In the same assays marmycin B was significantly less potent with a mean IC50 value of 3.5 µM (Martin *et al.,* 2007).

Streptomyces luteoverticillatum 11014 Li *et al.* (2006) isolated from underwater sediment at 20 m depth collected off the coast of Taipingjiao, Qingdao, China, is the producer of four known butenolides: (4*S*)-4,10- dihydroxy-10-methyl-undec-2-en-1,4-olide Cho *et al.* (2001), (4*S*)-4,10-dihydroxy-10-methyl-dodec-2-en- 1,4-olide (Mukku *et al.,* 2000; Cho *et al.,* 2001) and two diastereomeric (4*S*)-4,11-dihydroxy-10-methyl-dodec-2-en-1,4- olides. The four butenolides showed cytotoxic activity against human leukemia K562 with IC50 values of 8.73, 6.29, and 1.05 µmol/ml and murine lymphoma P388 cell lines with IC50 values of 0.34, 0.19, and 0.18 µmol/ml, respectively.

In this study, a butenolide was detected in isolate Ruj 7-1. 4, 8, 12, 16-Tetramethylheptadecan-4-olide was detected at 26.940 min retention time and its activity is still unknown. This butenolide could be having novel antitumoral suppression activity in its application.

A new class of 2-alkylidene-4-oxazolidinone, exhibiting an unprecedented antibiotic pharmacophore, was isolated from a marine actinomycete (NPS8920) (Macherla *et al.,* 2007; Michelle *et al.,* 2008). A series of three compounds in this class, lipoxazolidinones A to C, have been isolated, with the most potent activity against Anti-methicillin-resistant *Staphylococcus aureus* (MRSA) and Anti-vancomycin-resistant Enterococci (VRE).

In this study, two chemical compounds relating with lipoxazolidinones were detected; 2-Piperidinone from isolate Chy 4-10 at 14.151 min retention time and 2-Pyrrolidinone from isolate Chy 2-3 at 12.449 min retention time. The activity of these two chemical compounds is unknown and further purification and testing would provide more information on their activities.

Today, the urgent need for new antimalarials requires the discovery of small and inexpensive molecules. Using an SYBR Green bioassay on the parasite's erythrocytic stages Jacques *et al.* (2008) carried out research on secondary metabolite produced by a marine actinomycete Salinispora tropica that had significant antimalarial activity. A pure amide chemical compound, salinosporamide A, was tested for its inhibitory activity against parasite development in vitro *(*P. falciparum*)* and *in vivo (*P. yoelii). The finding demonstrated that natural products remain one of the most important sources of medicines against the parasite. In this research, all the studied isolates produced amides that were detected at different retention times; N-(4-Methoxyphenyl)-2-hydroxyimino-acetamide at 23.289 min, L-Prolinamide at 20.982 min, Acetamide,2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)- at 23.737 min, Formamide,N-(2,4-diamino-1,6-dihydro-6-oxo-5-pyrimidinyl)- at 29.157 min, N-Methoxymethyl-N-methylformamide at 11.015 min, Propanamide, 2-methyl- at 9.694 min and Propanamide, N,N-dimethyl- at 17.667 min. Activities of these amide chemical compounds need to be researched upon for they could be holding novel properties that would help in tackling the challenges of malaria at hand. Other groups of chemical compounds were also detected such as alcohols and hydrocarbons.

5.0 Conclusion and Recommendation

Physiochemical characterization of the isolates showed that optimal growth of the isolates was observed at pH values 6 and above. Optimum growth temperatures were observed between 27.5°C to 32.5°C. Growth of the isolates in culture medium at different NaCl levels (varying between 5 and 32.5g/l) indicated tolerance to salinity and an adaptability of these isolates to varying NaCl concentrations. In addition, glucose and xylose were the most utilized sugars for growth of the isolates whereas arabinose, inositol and mannitol were the least preferred sugars. The isolates showed antimicrobial activity and also produced a wide range of chemical compounds indicating they could be an important source of different antimicrobial compounds. *Streptomyces* have been well known during the last seventy years as prolific producers of new bioactive compounds, antitumor drugs included. With the increasing development of oceanographic studies leading to the isolation of new Actinomycetes from marine sources, new prolific genera in the production of useful compounds have been found, such as *Salinispora*. Moreover, protected terrestrial ecosystems may harbor a myriad of new Actinomycetes providing novel structural diversity to be discovered as evidenced by this study. Besides, the continuous effort to unravel the biosynthesis of the already known compounds and the isolation and characterization of their biosynthesis gene clusters may lead to the development of new antitumor compounds, hopefully with improved therapeutic properties, by using combinatorial biosynthesis approaches. And lastly, adoption of innovative techniques such as coculturing, cross species induction and biofilm development, may further facilitate the discovery of new and useful antimicrobial compounds.

Acknowledgement

This work was financially supported by Jomo Kenyatta University of Agriculture and Technology and Prof. Hamadi Iddi Boga. I am extremely indebted to them for the research funds without which it would not have been possible to do this work.

References

Alexandra, M. C. R., (1997). Regulation of glucose metabolism in the Actinomycetes *Amycolyptopsis methanolica* and *Streptomyces coelicolor* A3 (2). PHD thesis, University of Groningen, Germany.

Baltz, R. H. (2008). Renaissance in antibacterial discovery from Actinomycetes. *Curr. Opin. Pharmacol*., **8**, pp 557-563.

Berdy, J. (1995). Are Actinomycetes exhausted as a source of secondary metabolites? In: Debabov V, Dudnik Y, Danlienko V (Eds) Proceedings of the 9th international symposium on the biology of Actinomycetes. All-Russia Scientific Research Institute for Genetics and Selection of Industrial Microorganisms, Moscow, pp 13–34.

Berdy, J. (2005). Bioactive microbial metabolites. *J. Antibiot.* **58**, pp 1-26.

Bergey's manual of determinative bacteriology 2000 Actinomycetales, 9th edition.

Bibb, M. J. (2005). Regulation of secondary metabolism in streptomycetes. C*urr Opin Microbiol.,* **8**, pp 208–215.

Cho, K. W., Lee, H. S., Rho, J. R., Kim, T. S., Mo, S. J. and Shin, J. (2001). New lactone- containing metabolites from a marine-derived bacterium of the genus *Streptomyces*. *J Nat Prod.* **64**, pp 664–667.

Chun, J., Bae, K.S., Moon, E.Y., Jung, S.O., Lee, H.K. and Kim, S.J. (2000). *Nocardiopsis kunsanensis* sp. nov., a moderately halophilic actinomycete isolated from a saltern. *Int. J. Syst. Evol. Microbiol.*, **5,** pp 1909-13.

Demain, A. L and Davies, E. J. (1999). Manual of Industrial Microbiology and Biotechnology. 2nd Edition. American Society of Microbiology, 1325, Massachusetts Avenue, N.W. Washington DC.

Gava, C. A. T. (1998). Seleção de estreptomicetos para controle biológico de *Ralstonia solanacearum* e *Erwinia carotovora*. Rio de Janeiro: Universidade Federal do Rio de Janeiro, 114p. dissertação (Mestrado).

Goodfellow, M., Stanton, L. J., Simpson, K. E. and Minnikin, D. E. (1990). Numerical and chemical classification of *Actinoplanes* and some related Actinomycetes. *J. Gen. Microbiol.*, **136**, pp 19-36.

Gorajana, A., Kurada, B.V., Peela, S., Jangam, P., Vinjamuri, S., Poluri, E. and Zeeck, A. (2005). 1-Hydroxy-1-norresistomycin, a new cytotoxic compound from a marine actinomycete, *Streptomyces chibaensis* AUBN1/7. *J. Antibiot*., **58**, pp 526-529.

Gorajana, A., Venkatesan, M., Vinjamuri, S., Kurada, B.V., Peela, S., Jangam, P., Poluri, E. and Zeeck, A. (2007). Resistoflavine, cytotoxic compound from a marine actinomycete, *Streptomyces chibaensis* AUBN1/7. *Microbiol. Res*., **162**, pp 322-327.

Hendrickson, D. A. and Krenz, M. M. (1991). Reagents and stains. In *Manual of Clinical Microbiology*, pp. 1289–1314. Edited by A. Balows, W. J. Hausler, Jr, K. L. Herrmann, H. D. Isenberg and H. J. Shadomy. Washington, DC: American Society for Microbiology.

Jacques, P., Eric, M., Nadia, P., Stéphane, B., William, F., Paul, J. and Karine, L. R. (2008). Marine Actinomycetes: A New Source of Compounds against the Human Malaria Parasite. PMCID: PMC2391291. **3**(6), pp e2335.

Jensen, P.R., Mincer, T.J., Williams, P.G. and Fenical, W. (2005). Marine actinomycete diversity and natural product discovery. *J. Antonie Van Leeuwenhoek*. 87:43–48.

Kieser, T., Bibb, M. J., Buttner, M. J. and Chater, K. F. (2000). Practical *Streptomyces* genetics. Hopwood D. A. (Ed.). John Innes Centre, Norwich, England.

Kock, I., Maskey, R.P., Biabani, M.A., Helmke, E. and Laatsch, H. (2005). 1-Hydroxy-1-norresistomycin and resistoflavin methyl ether: new antibiotics from marine-derived streptomycetes. *J. Antibiot*., **58**, pp 530-534.

Lee, H. B., Kim, Y., Kim, J. C., Choi, G. J., Park, S. H., Kim, C. J. and Jung, H. S. (2005). Activity of some aminoglycoside antibiotics against true fungi, *Phytophthora* and *Pythium* species. *J Appl Microbiol.* **99**, pp 836–843.

Li, D. H., Zhu, T.J., Liu, H. B., Fang, Y. C., Gu, Q. Q. and Zhu, W. M. (2006). Four butenolides are novel cytotoxic compounds isolated from the marine-derived bacterium, *Streptoverticillium luteoverticillatum* 11014. *Arch. Pharm. Res*., **29**, pp 624-626.

Macherla, V.R., Liu, J.N., Sunga, M., White, DJ., Grodberg, J., Teisan, S., Lam, K.S. and Potts, B.C.M. (2007). Lipoxazolidinones A, B, and C: antibacterial 4-oxazolidinones from a marine actinomycete isolates from a Guam marine sediment. *J Nat Prod.,* **70**, pp 1454–1457.

Martin, G. D., Tan, L. T., Jensen, P. R., Dimayuga, R. E., Fairchild, C. R., Raventos-Suarez, C. and Fenical, W. (2007). Marmycins A and B, cytotoxic pentacyclic C-glycosides from a marine sedimentderived actinomycete related to the genus *Streptomyces*. *J. Nat. Prod*., **70,** pp 1406- 1409.

Michelle, S., Teisan, S., Tsueng, G., Venkat, M. and Kin, L. (2008). Seawater requirement for the production of lipoxazolidinones by marine actinomycete strain NPS8920. *J Ind Microb Biotech*., **35:** pp 761–765.58.

Moreira, F. M. S. and Siqueira, J. O. (2002). Microbiologia e bioquímica do solo. Lavras: UFLA, 626p.

Mukku, V. J., Speitling, M., Laatsch, H. and Helmke, E. (2000). New butenolides from two marine Streptomycetes. *J. Nat. Prod*., **63**, pp1570-1572.

Newman, D. J. and Cragg, G. M. (2007). Natural products as sources of new drugs over the last 25 years. *J.Nat. Prod.,* **70**, pp 461-477.

Olano, C., Méndez, C. and Salas, J. A. (2009). Antitumor compounds from Actinomycetes: from gene clusters to new derivatives by combinatorial biosynthesis. *Nat. Prod. Rep*., **26**, pp 628-660.

Pathom-aree, W., Stach, J. E. M., Ward, A. C., Horikoshi, K., Bull, A. T. and Goodfellow, M. (2006). Diversity of actinomycetes isolated from Challenger Deep sediment (10,898 m) from the Mariana Trench. *Extremophiles,* **10**, pp 181–189.

Sanchez-Lopez, J. M., Martinez Insua, M., Perez Baz, J., Fernandez Puentes, J. L. and Canedo Hernandez, L.M. (2003). New cytotoxic indolic metabolites from a marine *Streptomyces*. *J Nat Prod*., **66**, pp 863–864.

Sanglier, J. J., Haag, H., Huck, T. A. and Fehr, T. (1996). Review of actinomycetes compounds 1990-1995. *Expert Opin Invest Drugs,* **5,** pp 207–223.

Sola-Landa, A., Moura, R. S. and Martin, J. F. (2003). The two-component PhoR-PhoP system controls both primary metabolism and secondary metabolite biosynthesis in *Streptomyces lividans*. *Proc Natl Acad Sci USA*, **100**, pp 6133–6138.

Waksman, S. A. (1950). The actinomycetes, their nature, occurrence, activities, and importance. Waltham, Mass. Chronica Botanica Co.

Waksman, S. A. (1962). *The actinomycetes*. Baltimore, Williams and Wilkins.

Waksman, S. A. (1967). The actinomycetes; a summary of current knowledge. New York, Ronald Press.

Watve, M. G., Tickoo, R., Jog, M. M. and Bhole, B. D. (2001). How many antibiotics are produced by the genus *Streptomyces*? *Arch Microbiol*., **176**, pp 386-390.

Williams, S. T., Goodfellow, M. and Alderson, G. (1989). Genus *Streptomyces* Waksman and Henrichi 1945.339^{AL}. **In** Bergey's manual of Determinative Systematic Bacteriology, Vol .4, pp.2453-2492. Edited by S. T. Williams, M. E .Sharpe and J. G. Holt. Baltimore: Williams and Wilkins.

IN VITRO REGENERATION OF *THEVETIA PERUVIANA* PERS.K.SCHUM, FAMILY APOCYNACEAE

P. O. Odhiambo[1], M. Makobe[2], H. BoAg, A. Muigai[2] and H. Kiesecker[3]
[1]Masinde Muliro University of Science and Technology, Kakamega, Kenya
E mail: pissoonyango2@yahoo.com. ,
[2]Jomo Kenyatta University of Agriculture and Technology
[3]DSMZ
E-mail: pissoonyango2@yahoo.com

Abstract
The objective of this study was to develop and optimize *in vitro* protocol for regeneration of soma clonal variants of *T.peruviana* aimed at obtaining glycoside free or low glycoside plantlets with high oil and proteins content through tissue culture technique in order to develop new varieties which has novel traits compared to the existing landraces. *T.peruviana* seedlings germinated from mature fruits of orange flowering variety of *T. peruviana* trees were used. Young but enlarged leaves next to the shoot tip were excised as source of explant. Callus initiation media consisted of MS salts, vitamins plus 8 g / l agar agar, 30 g / l sucrose, 2.0 mg / l dichlorophenoxyacetic acid (2,4-D) supplemented with 0.1 mg / l of kinetin at pH of 5.75 at 22^{o}C to 24^{o}C and 12 hour darkness during the night and 12hrs lighting from fluorescent tubes during the day. Shoot regeneration medium consisted of MS media salts, vitamins, supplemented with 3 mg / l of 2 ip, 8 g / l agar agar, 30 g / l of sucrose, at pH of 5.75 were incubated at 25^{0}C-27^{0}C, with continuous lighting from florescence tubes in the growth chamber. Rooting was initiated by incubating single shoots into each media bottle containing 30 ml of MS media salts, vitamins, 1 g of glycine, 0.2 g of biotin, 3 mg/l of Indole-3-butyric acid (IBA), 8 g of agar agar and 30 g/l sucrose. It was noted that plantlets of *T.peruviana* regenerated after 12-24 months.

Key words: *Thevetia peruviana*, *in vitro* regeneration, Murashige and Skoog, callus

1.0 Introduction

Thevetia peruviana Pers.K.Schum synonym *T.nerifolia* A.Juss belongs to family Apocynaceae. The family is a major centre of interest to botanists, phyto-chemists, pharmacologists and agriculturalists since the members are well known for drugs, arrow poisons, alkaloids, rubber and as ornamentals (Van Beek *et al.*, 1984). *T. peruviana* has great potential for vegetable oil, pharmaceuticals and proteins production (Supinya *et al.,*2002,Usman *et al.,* 2009, Quilichini and Bertucat, 1956, Arora and Battacharya, 1967, Jain and Yadav, 1991).

In vitro culture of higher plants is the culture on nutrient media under sterile conditions of plants, embryos, organs, explants, tissues, cells and protoplasts of higher plants, (Pierik, 1992). Murashige and Skoog's culture medium is the most used tissue culture medium, (Murashige and Skoog, 1962). The establishment of cell cultures, the cell growth, and accumulation of secondary metabolites can be affected by the illumination conditions, the hormonal composition of the culture medium, and the organic and in organic composition of the medium itself, (Duchefa, 1998-9). Plant growth regulators in the tissue culture medium can be manipulated to induce callus formation and subsequently changed to induce embryos from the callus. Furthermore subculture of responsive embryos or embryogenic callus produces shoots or somatic embryos depending on the medium and plant growth regulators used and vary with plant type. *In vitro* culture technology has been proven to be effective in some cases for the production of secondary plant metabolites such as taxol. However little attention has so far been put on the development of *in vitro* cultures of *T.peruviana*. Most of the studies on *T.peruviana* have focussed on somatic embryogenesis rather than secondary metabolites, (Abha Sharma and Anjani Kumar, 1994 and Anjani Kumar, 1992).

In this study the main objective was to develop and optimize an *in vitro* regeneration protocol for soma clonal variants of *T.peruviana*, aimed at obtaining glycoside free or low glycoside plantlets with high oil and proteins content through tissue culture as a step towards development of new varieties with novel traits compared to the existing landraces in Kenya.

Dedifferentiation and loss of thevetin in *T. peruviana* callus was first reported in 1981. The cotyledonary callus tissue of Yellow Oleander was found to contain thevetin, a cardioactive glycoside in the early callus tissue which gradually disappeared after six months of regular sub-culturing. Modification of environmental conditions or nutrition could not induce thevetin synthesis in the old callus tissue. Slight variation at genotypic level has also been reported. Cardenolide content of different genotypes of *T. neriifolia* and *Nerium odorum* were investigated. In spite of distinct morphological differences between varieties of *T.neriifolia* and *Nerium odorum* all varieties of *T.neriifolia* were similar in their cardenolide profiles. However there was slight variation in thevetin content at varietal level in *T. neriifolia,* (S.Gopa and Datta P.C, 1981).

Development of anthoxanthins and carotenoids in *T.nerifolia* anther and ovarian tissues in vitro had been reported. The ovaries and wall layers of anthers of *T.neriifolia* proliferate into snowy callus showing rapid growth in about a fortnight. The callus tissues showed development of anthoxanthins and carotenoids. Anther tissues contained kaemferol, quercetin, carotenes, and cyaniding-3-glycosides abundantly whereas these were absent in the ovarian tissues. Lutein and anthocyanin precursor flava 3:4 diols were present in both the tissues but only ovaries developed polyoxy pigments, (Marthur *et al.,* 1976).

Biotransformation of cardenolides by cell suspension cultures in *Digitalis lanata* and *T.peruviana* had also been reported. In cell suspension cultures of *T.peruviana*, cymarin was glycosilated to k-strophanthin, peruvoside was glucosylated to a diglycoside and also reduced at the C-10 formyl group to give neriifolin, thevetin A was deglucosylated to the corresponding diglycoside and then to peruvoside, thevetin B was deglucosylated to its diglycoside and then to neriifolin, lanatoside A was

deglucosylated and deacetylated to digitoxin. Similar biotransformations were reported on *D.lanata*. However neither of the two plant cultures was able to remove the digitose moiety *in vitro,* (Doeller, P.C *et al.,* 1977).

Biotransformation of cholesterol to thevetin in early callus of *T.peruviana* had also been reported. The study found out that thevetin synthesis by cotyledonary callus of *T.peruviana* on Murashige and Skoog's culture medium supplemented with cholesterol increased with increase in cholesterol concentrations up to 300mg/100mL; however thevetin yield gradually decreased at higher concentrations. Callus growth however declined in response to cholesterol, (Gosh Gopa *et al.,* 1983).

Elicitation with methyl-jusmate has been reported to stimulate peruvoside production in cell suspension cultures of *T.peruviana*. The elicitor effect of Methyl –jusmate was reportedly studied in cell suspension cultures established in Schenk and Hildebrandt (SH) medium. The best results were obtained at a concentration of 100mg l^{-1} of Methyl jusmate applied at the beginning of the culture which induced extra cellular peruvoside production of 8.93 mg l^{-1}, (Mario Arias Zabala *et al.,* 2009).

Sharma and Kumar, 1994 regenerated plantlets from leaf derived callus of a mature *T. peruviana* plant. The callus were regenerated in MS media containing 2mg/L-2,4D plus 0.1mg/L Kinetin. The calli were sub-cultured in a lower concentration of 0.1mg/L, 2,4D supplemented with 2mg/L 2ip for embryogenesis. The developing embryos were then transferred to MS media lacking growth regulators for embryo maturation. The mature embryos were then sub-cultured into modified half strength MS media resulting into 80% regeneration of plantlets *in vitro*.

2.0 Materials and Methods

The tissue culture experiments were carried out at the Institute for Biotechnology Research (IBR) at JKUAT and DSMZ Tissue culture Laboratories in Germany.

2.1 Source of Explants

T.peruviana seeds were harvested from mature fruits of orange flowering variety of *T. peruviana* trees cultivated in an experimental plot at Jomo Kenyatta University of Agriculture and Technology (JKUAT). The seeds were planted in polythene pots measuring 5 cm wide and 10 cm high. The pots were filled with loamy soil watered once a day in the morning at 8.00 am. The pots were kept on the laboratory side bench, next to the windows and in green house conditions until germination occurred. At DSMZ yellow oleander seeds were germinated under laboratory condition set with tropical temperatures ranging from 20-30^{0}C and watering regimes similar with JKUAT.

Young but enlarged leaves next to the shoot tip were excised from the young(5-10 days old) germinated seedlings and cut into leaf discs measuring 5 mm in diameter using heat sterilized scalpel. The seedlings aged 10-14 days were used as explants source, Fiure 1 below:

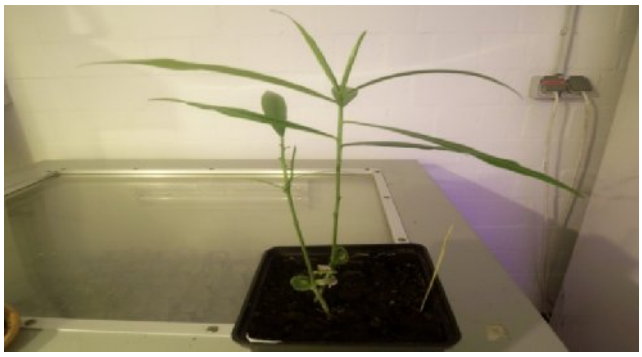


Figure 1: Young T.peruviana seedlings used source of as explants germinated at DSMZ

2.2 Preparation of the Explants for Callus Initiation and Growth

The excised leaf discs were surface sterilized by immersing in 50 ml of 70 % ethanol for 1 minute and then transferred into 50 ml of 2 % sodium hypochlorite solution for 15 minutes. The sodium hypochlorite solutions were prepared from commercial "jik" containing 3.5 % sodium hypochlorite by diluting 57 ml of the "jik" to 100 ml with distilled sterilized water.

In a lamina flow the sterilized explants were then transferred into sterilized petri dishes and rinsed thrice with distilled sterilized water. Using heat-sterilized forceps, the leaf discs were inoculated one each into each sterilized culture glass bottles measuring (15 x 5 cm) and disposable petri dishes containing 30 ml of Murashige and Skoog (MS) culture medium and the screw caps and top covers tightly closed.

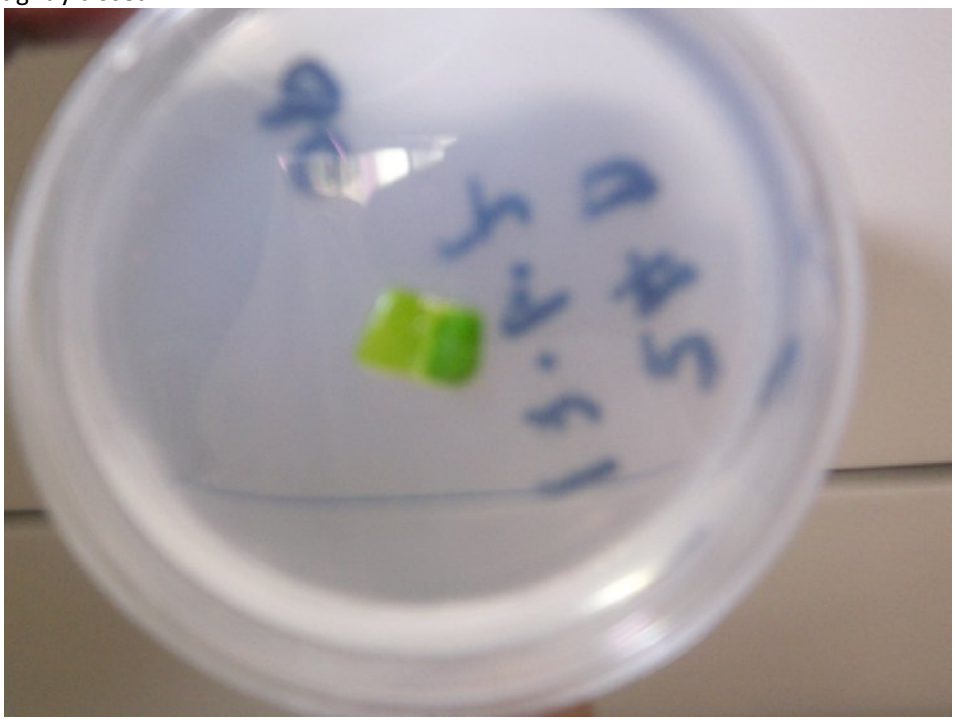


Figure 2: Leaf disc in MS media enclosed in a petri dish for callus initiation

2.3 Callus Initiation Medium

The callus initiation media consisted of MS salts and vitamins plus 8 g / l agar agar, 30 g / l sucrose, 2.0 mg / l dichlorophenoxyacetic acid (2,4-D) supplemented with 0.1 mg / l of kinetin.

The pH of the media was set at 5.75 using 0.1 M hydrochloric acid and 0.1 M sodium hydroxide solutions. The media was autoclaved for 15 minutes at 1.5 kg cm^{-1} pressure and temperature 121^{o}C. For initiation of callus, the culture bottles were incubated in the growth chamber maintained at temperatures between 22^{o}C to 24^{o}C and 12 hour darkness during the night and 12hrs lighting from fluorescent tubes during the day.

The hormone concentrations were arrived at after performing trial experiments involving (0.5, 1.0, 1.5, 2.0, 3.0 mg / l of 2, 4-D and 0, 0.05, 0.1, 0.15, 0.2, 0.3mg / l of kinetin. Each concentration for trial experiment had 20 replicates. After the trial experiments 2 mg / l of 2, 4-D and 0.1 mg / l of kinetin were determined as optimum for callus induction and used in subsequent experiments.

Other auxins, indoleacetic acid (IAA) and napthaleneacetic acid (NAA) at concentrations as above were also used in an attempt to induce callus without success.

2.4 Callus Proliferation Medium

For further growth and multiplication, the callus was maintained by culturing in MS media salts, vitamin solutions, 8 g agar agar, 30 g / l of sucrose supplemented with 3 mg / l of BAP plus 0.1 mg/l 2, 4-D. The pH was 5.75 for two months with regular sub-culture into fresh medium after every two weeks. Other concentrations at (1, 2, 3 and 4 mg / l of BAP and 2 ip and 0, 0.05, 0.1, 0.15 0.2 mg / l of kinetin and 2,4-D were used to arrive to an optimum of 3 mg / l of BAP and 0.1 mg / l 2,4-D for callus proliferation.

2.5 Callus Maturation andEmbryogenesis

Callus maturation was attained by sub culturing 14 weeks old calli into hormone free MS media supplemented with B5vitamins. The pH was maintained at 5.75 and inoculants kept at 22-24^{0}C with regular subculture into fresh maturation media.

2.6 Cell Suspension Culture

Cell suspension cultures were established using liquid MS medium and subcultured into fresh liquid MS media after every 2 weeks. The liquid MS media without agar was supplemented with 3 mg / l of BAP plus 0.1 mg/l 2,4-D. The pH was 5.75. In a lamina flow about 1cm^{3} of callus was suspended in 15ml of the media in 50ml sterilized conical flasks covered with sterilized aluminium foil. The inoculated conical flasks were then placed on a rotary at 50 revolutions per minute at between 22^{o}C to 24^{o}C and 12 hour darkness during the night and 12hrs lighting from fluorescent tubes during the day. The large clumps of embryogenic calli in the liquid media were then plated on the solid regeneration MS media supplemented with.

2.7 Regeneration and Rooting

For plant regeneration embryogenic callus, which was greenish in colour was separated from whitish non-embryogenic callus using sterilized scalpel. About 1-2 g of excised embryogenic callus was inoculated into 30ml shoot regeneration media.

The shoot regeneration medium consisted of MS media salts, vitamins, supplemented with 3 mg / l of 2 ip, 8 g / l agar agar, 30 g / l of sucrose, at pH of 5.75 and incubated at 25^{0}C-27^{0}C, with continuous lighting from florescence tubes in the growth chamber at IBR and at DSMZ. This concentration of 2 ip was arrived at after several trial experiments involving use of (1, 2, 3, and 04

mg / l of 2 ip). The regenerated shoots measuring 2-5 cm was transferred to rooting media after 13 weeks of regular sub-culture into fresh shooting media after every two weeks.

Rooting of the shoot regenerates was initiated by incubating single shoot into each media bottle containing 30 ml of MS media salts, vitamins, 1 g of glycine, 0.2 g of biotin, 3 mg/l of Indole-3-butyric acid (IBA), 8 g of agar agar and 30 g/l sucrose. The incubation temperatures remained at 25^0-27^0C with 12hr darkness and 12hr lighting from fluorescent tubes. This concentration of IBA was reached after trial experiments using 0.1, 0.2, 0.3, and 0.4 mg/l of IBA. Each trial had 20 replicates.

3.0 Results

Callus formation was successful and estimated at 80%, observed after 2 weeks in culture media consisting of MS salts, vitamins plus 8 g / l agar agar, 30 g / l sucrose, 2 mg / l 2, 4-D supplemented with 0.1mg/l of kinetin. Figure greenish embryogenic (M) callus and regenerated into shoots (R) in Figure 1. Trials using IAA and NAA failed to induce callus growth. 2-4, D was very effective in induction of callus even at as low values as 0.5 mg / l.

Callus proliferation was attained in culture media consisting of MS media containing vitamins plus 8 g / l agar agar, 30 g / l sucrose, supplemented with 3 mg / l BAP and 0.1mg 2, 4-D. Cell suspensions cultures developed successfully in the liquid media with the formation of large clumps of embyogenic callus which regenerated into plantlets on plating on MS solid regeneration media supplemented with 3 mg / l of 2 ip, 8 g / l agar agar, 30 g / l of sucrose, at pH of 5.75 and incubated at 25^0C-27^0C, with continuous lighting from florescence tubes in the growth chamber at DSMZ.

Callus growth and maturation was achieved by maintaining the callus in hormone free MS media with B5 vitamins, 8 g agar agar, 30 g / l of sucrose at pH of 5.75 for two months with regular sub-culture into fresh medium after every 2-3 weeks regularly. The greenish embryonic callus was formed from the whitish non embryogenic callus during this stage.

The embryogenic calli were sub-cultured into shooting media. Shoots measuring 1-3 cm tall, with 2-4 green leaflets measuring 1-2cm long were obtained after 12 weeks. The shoot regeneration media consisted of MS media salts, vitamins, supplemented with 3 mg / l B.A.P, 8 g / l agar agar, 30 g / l of sucrose. Trial experiments with kinetin failed to induce shoot formation.

Rooting rate was as low as 40 % obtained after 3-6 weeks of incubation of the shoots into media bottle each containing 30 ml of MS media salts, vitamins, 1 g of glycine, 0.2 g of biotin, 0.3 mg / l of Indole-3- butyric acid (IBA), 8 g of agar agar and 30 g/ l sucrose, see plate 3. The whitish roots that measured 2-4 cm long appeared like prop roots formed at the base of the shoot and grew into the media. Although IBA induced rooting in presence of increased concentration in levels of glycine and biotin, it failed to induce root formation in the absence of the two amino acids.

Plate 2

Figure 3: Regeneration of T. peruviana in vitro via callus

L. embryogenic (greenish) and non embryogenic (whitish) calli of *T.peruviana*
M. embryogenic callus of *T. peruviana in vitro* R. *in vitro* shooting of *T. peruviana* from the embryogenic calli.

Figure 4: T.peruvaina callus undergoing somatic embryogenesis at DSMZ laboratory, Germany

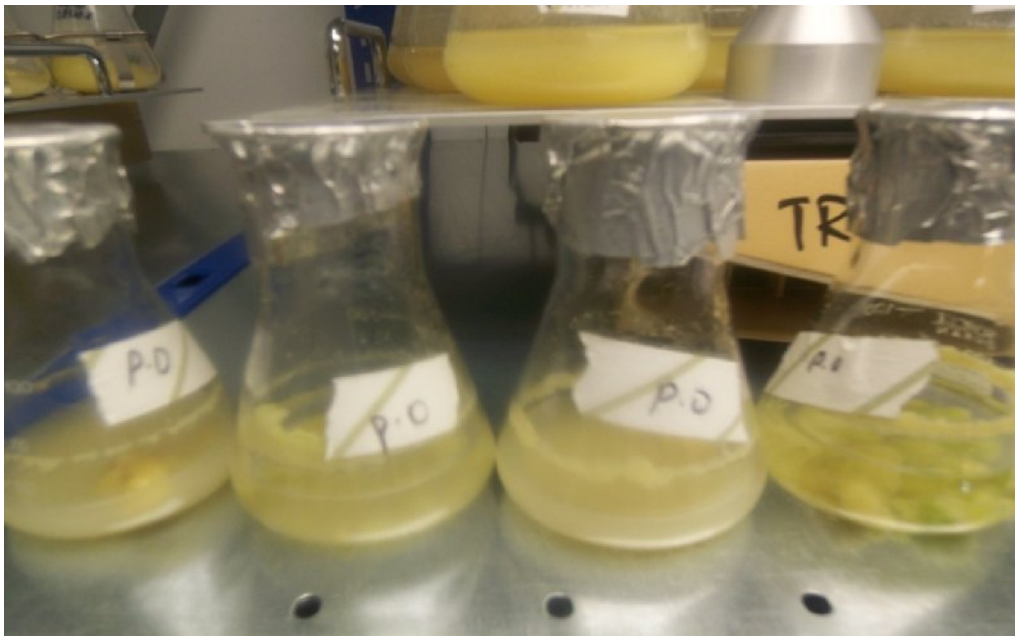


Figure 5: Cell suspension cultures of T.peruviana at DSMZ laboratory

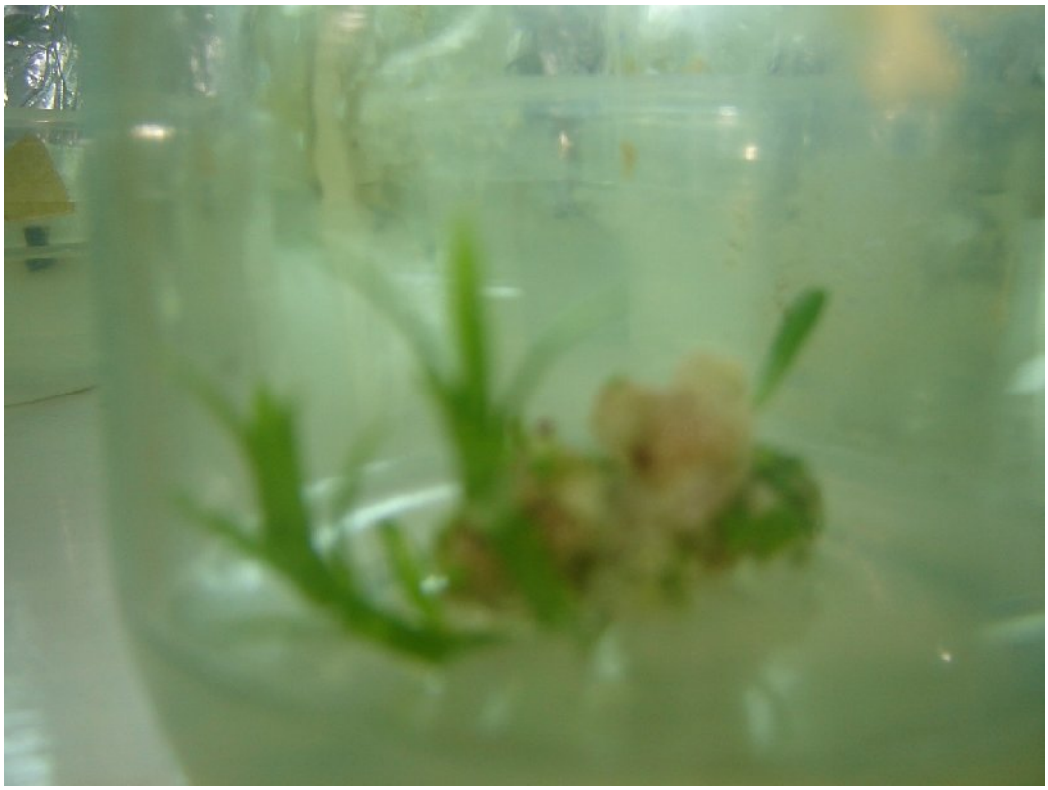


Figure 6: Regenerating T.peruviana plantlets at JKUAT, IBR laboratory

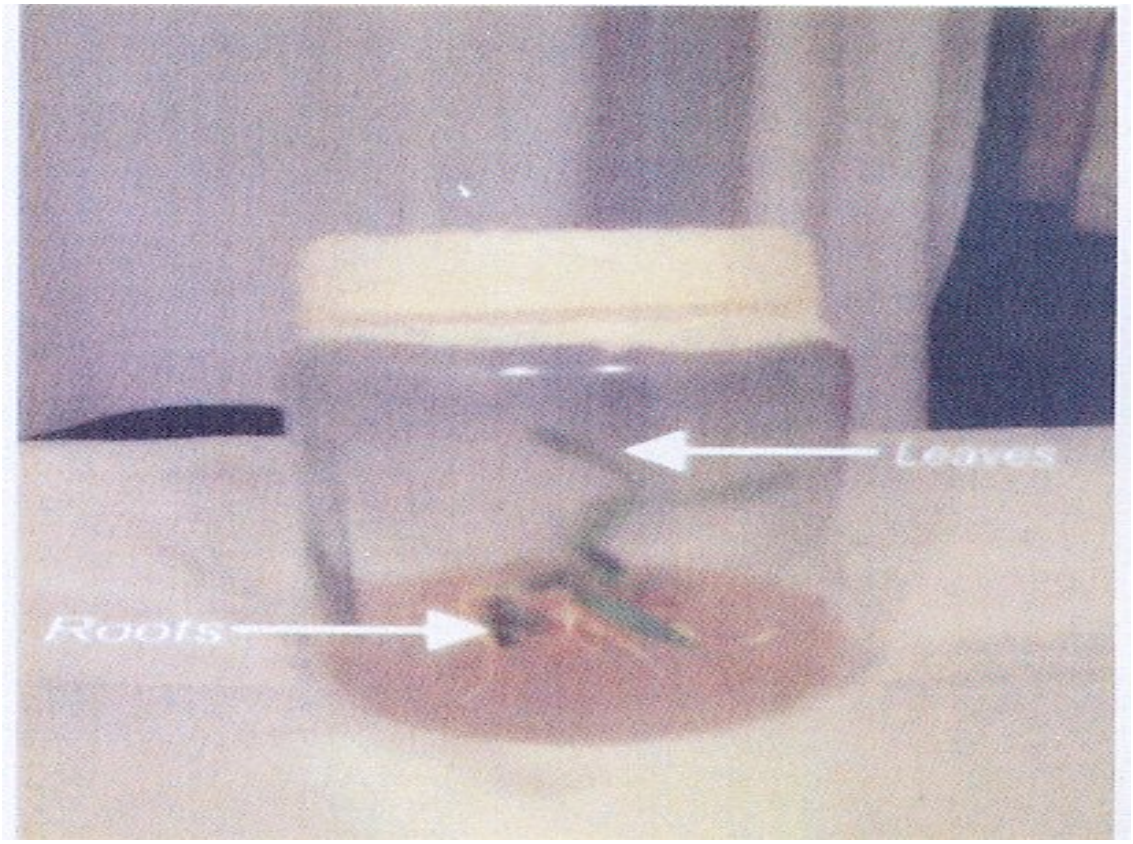


Plate 7: T.peruviana plantlet rooting in vitro at IBR, JKUAT

4.0 Discussion

The leaf discs from young *T. peruviana* seedlings exhibited good dedifferentiation characteristics into callus *in vitro* induced by plant growth regulator 2,4-D. This could be attributed to their young age and an early stage in their physiological development and due to the physiological effect of 2, 4-D on wounded plant parts like the leaf discs. 2,4D is largely used as a herbicide in plants due to its ability to retard plant growth and development.

The age and physiological state of the parent plant has been known to determine the success of the *in vitro* regeneration potential of the explant. Leaf explants from young pre-flowering, and healthy plants had been recommended (Evans *et al.,* 1981). The whitish callus developed into embryos, which were greenish in colour, which later regenerated into whole plantlets, when 2, 4-D was withdrawn and replaced with cytokinin (BAP) since 2, 4- D is known to inhibit embryo, shoot and roots development (Fujimura and Komamine, 1975). Somatic embryos are formed from plant cells that are not normally involved in the development of embryos. No seed coat or endosperm is formed a round somatic embryos. Application of this somatic embryogenesis include, clonal propagation of genetically uniform plant material, elimination of viruses, provision of source tissue for genetic transformation, generation of whole plants from single cells and development of synthetic seed technology, (Dodeman *et al.,*1997). In other reported cases, 2, 4-D has been used alone or with a low cytokinin concentration to initiate callus in over 57 % of successful embryogenic cultures in the world (Evans *et al.,* 1981). Generally a high concentration of auxin and a low concentration of cytokinin in the medium promote abundant cell proliferation with the formation of callus (John and Lorin, 1982).

Callus maturation and embryo development was realized in 2, 4 D free culture media. It was noted that BAP was very crucial during callus proliferation, embryo development and the subsequent shooting stage. Cytokinins are known to promote embryonic accumulation of proteins and biosynthesis of polyamines, required for rapid cell division. The concentration of 6, benzylaminopurine was very critical during embryo development and shoot regeneration *in vitro*. Cytokinins are very important for fostering embryo maturation and especially cotyledon development and change in auxin type or concentration is a prelude to embryo development (Fujimura and Komamine, 1975). Amino acid glycine, vitamin solutions in the rooting media specifically biotin and the auxin (IBA) played a crucial synergistic role in the root development stage in the *in vitro* regeneration of *T. peruviana.*

Increased concentration and bioavailability of glycine promoted root development by acting as a source of organic nitrogen, which is essential for enzyme, and protein synthesis required for root development. The vitamins specifically biotin which were added in solution form to the media played a key role as well as the amino acid glycine during the root development stage by hastening the process. Vitamins are known to be physiologically significant as enzyme activators and indeed the biotin played a key role in the rooting stage by activating the enzymes required for protein synthesis. Earlier work shows that biotin is a water-soluble vitamin which is physiologically important as cofactor of four adenosine tri-phosphate (ATP) dependent carboxylases namely acetyl Co-A carboxylase, pyruvate carboxylase, propionyl-Co-A carboxylase, and β-methyl crotonyl-Co-A. It is used as ATP carrier in the carboxylation reactions (Tom, 1999). Vitamin D, its analogues, and other vitamins such as thiamine are anew class of plant growth substances known to promote, cell aggregation, growth and root development (Salisbury and Ross, 1986).

A short passage time of two weeks and sub-culture into fresh media was maintained since it is known that a shorter passage is recommended to maintain chromosome stability of cell cultures and replenish the nutrients in the growth media. Sub-cultures should be done frequently especially during late exponential growth phase and should never enter the stationery phase. Longer passage time before subculture is reported to be source of mutations in cultured plant cells (Kao *et al*., 1970).

Aseptic culture media was always maintained by the outlined sterilization procedures to provide the most favourable conditions containing essential macro and micro-nutrient salts, sugars, vitamins, amino acids and growth regulators to the cultured tissue as the same nutrients are in greater demand by the micro biota (John and Lorin, 1982). Cell suspension cultures produced large clumps of embryogenesis calli since there was uniform distribution of nutrients as well aeration due to the constant shaking.

5.0 Conclusion

This study revealed that plantlets can be regenerated by tissue culture via callus induction and can provide the basis for selection of plantlets with superior traits such as high oil yield, low or no glycoside content, rapid growth, and early maturity. The technique can also provide an opportunity for genetic engineering of the oil plant to incorporate other desirable genetic factors such as nitrogen fixation, which will be of great benefit to the farmers and vegetable oil industry. This study is useful since the species is currently growing in the wild without well documented information on its propagation and improvement. Tissue culture is one of the best methods so far for generation of superior planting materials without use of irradiation and chemical mutants in *T.peruviana*.

References

Abha, S. and Anjan, K. (1994). Somatic embryogenesis and plant regeneration from leaf derived cell suspension of a mature tree-*Thevetia peruviana* L.Plant Cell Reports **14**, pp 171-174.

Akella, M., Khurana J. P. and Khurana P. (2003). Rapid induction of somatic embryogenesis by 2,4-D in leaf base cultures of wheat(*Triticum aestivum* L.). Plant Biotechnology, **20**(4), pp 267-273.

Arora, R. B and Rangaswami, S., (1972). Peruvoside and other cardiotonic glycosides of*Thevetia* neriifolia, *Indian Journal of Experimental Biology* **5**:31.

Dixon, R. A and Gonzales, R. A (1994). Plant cell culture. A practical approach 2nd edition,Oxford University press 127 – 135.

Doeller, P. C., Alferman, A. W., and Reinhard, E. (1977). Biotransformation of cardenolides by cell suspension cultures of *Digitalis lanata* and *Thevetia neriifolia*. *Planta Medica*. **31,** pp 1-6.

Dodeman, V. L., Ducreux, G., and Kreis, M. (1997). Zygotic embryogenesis versus somatic embryogenesis*. Journal of Experimental Botany* **48**(313), pp 1493-1509.

Duchefa Biochemicals Catalogue (1998-99). Plant Cell and Tissue Culture.Netherlands.

Evans, A. D, Sharp, R. W., Ammirato, P. V. and Yamada, Y. (1983). Handbook of plantcell culture. Techniques for propagation and breeding. 1,1-123.

Fujimura, T. and Komamine, A. (1975). Effects of various growth regulators on the embryogenesis of a carrot cell suspension culture. *Plant Sci. Lett.,* **5**, pp 359-364.

Gosh, G., Tikadar, S., Mazumdar,N. And Datta P. C. (1983). Biotransformation of cholesterol to thevetin in early callus of *Thevetia peruviana*. Indian Drugs, **21**, pp 88-89.

Jain, S. K. and Yadav, R. N. (1991). Protein bound amino acids of *Thevetia peruviana* leaves. *Journal of chemistry,* **3**, pp 304 – 6.

John, H. D. and Lorin W. R. (1982). Experiments in Plants Tissue Culture. Cambridge University Press.

Kao, K. N., Miller, R. A,Gamborg,O. L., and Harvey B. L. (1970). Variations in chromosomes in chromosome number and structure in plant cells grown in suspension cultures. Canadin *Journal of Genetics and Cytology*, **12**: pp 297-301.

Mario, A. Z., Monica, A., Juan, M. R., Luis, A. C. and Margarita, P. (2009). Elicitation with methyl-jasmonate stimulates peruvoside production in cell suspension cultures of *Thevetia peruviana.*In vitro Cellular and Developmental Biology-Plant. The Society for In vitro Biology.

Mathur, J. M. S, Majid, R. and Gupta, N. (1978). Physiology of sexually reproducing flowering plants. International symposium 494 – 6.

Murashige, T. and Skoog, F. (1962). A revised media for rapid growth and bioassays with tobacco tissue cultures. *Physiology of Plants*, **15**, pp 473-497.

Quilichini, R. and Bertucat, M. (1956). *Contribution a l' etude de huile extraite des graines an Thevetia neriifolia. Bull.Soc.Pharm. of Bordeaux* 95, 61-64.

Rachier, G. O. (2004). Introduction and Production of Cold Tolerant Oil Palm in Western Kenya. 9th Biennial KARI Scientific Conference and First Agricultural Research Forum.

Salisbury and Ross, (1986). Plant Physiology 3rd Edition, CBS Publishers.

Sen. D. and Datta, P. C. (1981). Dedifferentiation and loss of thevetin in *Thevetia peruviana* callus. *Planta Medica*., **41**, pp 415-417.

Supinya, T., Norio, N., Masao, H., Tamio, F. and Tanomjit, S. (2002). Flavanone and Flavanol Glycosides from the leaves of Thevetia peruviana and their HIV-1 Reverse Transcriptase and HIV-1 Integrase Inhibitory Activities. Chemical Pharmacology Bulletin.**50** (5), pp 630-635.

Tom, B. (1999). Nutritional Biochemistry 2nd Edition. Acad. Press.311-589.

Usman, L. A., 1Oluwaniyi, O. O., 1Ibiyemi, S. A., Muhammad, N. O. and Ameen, O. M., (2009). The potential of Oleander (*Thevetia peruviana*) in African Agricultural and Industrial development: A case study of Nigeria. J. Appl. Biosciences.

Van Beek, T. A., De Elder, A. M., Verpoork, R. and Baerleim, S. A. (1984). Antimicrobial, Antiomoebic, and Antiviral Screening of some Tabernaemontana species. *Planta Medica* **50**, pp 180 – 185.

ISOLATION AND CHARACTERIZATION OF BACTERIA ISOLATES FROM SOIL FEEDING TERMITES AND SOIL FROM JUJA AND KAKAMEGA FOREST IN KENYA

R. Ntabo[1], H. Boga[2], A. Muigai[3] and R. Mwirichia[4]
[1,2]Department of Botany, Jomo Kenyatta university of Agriculture and Technology, Nairobi, Kenya
[3,4]Institute for Biotechnology Research, Jomo Kenyatta university of Agriculture and Technology, Nairobi, Kenya
E- Mail: rnatbo@gmail.com

Abstract
In the last several years information on the gut ecosystem of termites has continued to be gathered. Most studies have been focused on wood feeding termites but studies on soil feeders remain sparse owing to their difficulty of establishing permanent laboratory cultures. The aim of this study was to isolate, characterize and identify bacteria resident in the soil feeding termite gut, mound and parent soil of *Cubitermes* species with the potential to produce antibiotics and enzymes for industrialization. The samples were collected from kakamega forest from two sites Kalunya Glade and Lirhanda Hill. The study was also extended to the soils found in Juja. Hundred and thirty seven (137) isolates were cultivated and isolated using dilute nutrient agar media and screened for their antagonistic effects on various test organisms. Fifty one percent of the isolates were antagonist to *Escherichia coli*. Fifty seven percent of the isolates were antagonists to *Bacillus subtilis* while 55% of the isolates were antagonist to *Candida albicans*. Enzymatic activities of the isolates showed that 65% of the total isolates were starch degraders, 54% were casein degraders and 68% of the isolates were able to liquefy gelatin. Eleven percent of the isolates were cellulose degraders the majority of which were obtained from termite gut and mound. Isolates from Juja soil had the highest number of non degraders as compared to Kakamega Forest soils. The isolates were characterized using morphological, biochemical and molecular methods. Phylogenetic analysis of amplified 16S rRNA gene sequence revealed majority of the isolates were closely related to *Bacillus* and *Brachybacterium* species and had showed *invitro* antagonistic effects. Gram negative bacterial isolates obtained were closely related to *Pseudomonas* species. In conclusion, the isolates were potential antibiotic producers with varying ability to degrade gelatin, casein, and cellulose an indication of the role they play in their habitat.

Key words: DNBA, colony forming unit, mound, gut, surrounding soil, Kalunya, Lirhanda hill, Juja

1.0 Introduction

Termites are a ubiquitous feature of tropical and subtropical soils, where their number exceeds 6000 m^{-2} and their biomass densities (> 50 g m^{-2}) often surpass those of grazing mammalian herbivores (0.0-7.5 g m $^{-}$2) (Collins and Wood, 1984). They belong to the order Isoptera (Nutting, 1990). This order contains five families of lower termites and one family of higher termites (Noirot, 1992). Termites are recognized as one of the major ecosystems engineers in tropical soils (Holt and lepage, 2000). Their impart on soils is caused by their feeding habits where they play a vital role as mediators of decomposition (Wood and jonson, 1986), humification, soil conditioning, fragmentation of organic detritus, nitrogen- fixation, aggregate- binding and formation of clay-mineral complexes (Lee and Wood, 1971; Collins, 1983; Tayasu *et al*., 1994). Termites construct mounds from the mineral matrix with faeces or saliva depending on termite species (Grassie, 1984). These mounds increase the microbial density as a result of high organic matter (Brauman *et al.,* 2000). Diverse micro organisms inhabite the intestinal tracts of all termite feeding groups (Brune, 1998; Brauman *et al.,* 2001). Most studies on termite gut microbial communities have focused on wood feeding termites; analogous studies of other feeding guilds, especially soil feeders are lagging behind, owing to their typically remote habitat, delicate nature and the difficulty of establishing permanent laboratory cultures (Bignell *et al*., 1980; Rouland *et al*., 1993). Soil on the other hand is a highly heterogenous environment (Rolf, 2004), that contains a high diversity of microorganisms (Liesack *et al*., 2002). These microorganisms influence above ground ecosystems by contributing to soil structure and fertility among other roles (O'Dounell et al., 2001). Soil microorganisms are a valuable source of natural products providing important antibiotics for pharmaceuticals, enzymes and bioactive compounds for industries (Strohl, 2000). However the emergence of multidrug resistance pathogens has rekindled the need to discover new antimicrobials from remote environments.

Cultivation independent approaches based on molecular analysis have revealed unexplored bacterial diversity in soil. However such methods do not provide speculation on the microbial physiology, abundance and ecological significance hence the need for cultivation dependent approaches (Embley and Stackebrandt, 1996). Cultivation-dependent approaches have exploited the diversity of soil microorganism for many years based on the cultivation and isolation of microbial species (Rolf 2004). However microorganisms are endemic to certain geographic regions hence various habitats in Kenya may harbor unique microbes as a result of different soil composition and size of particles (Torsvik, 2002). Low nutrient media specifically dilute nutrient broth plus agar (DNBA) media have been used in the recent past to isolate rarely isolated groups of bacteria from soil and wood feeding termites at 25ºC incubation temperature (Janssen et al., 2002; Stevenson *et al*., 2004). This media compares to those present in the natural environments (Button *et al*., 1993) preventing the growth of fast growing bacteria a situation that is common with high nutrient media (Zengler *et al*.,). The aim of this study was to cultivate bacteria from soil, mound and soil feeding termite gut using low nutrient media and characterize them so as to identify potential antibiotic and enzyme producers.

2.0 Materials and Methods

2.1 Sampling

2.1.1 Kakamega Forest

Kakamega Forest is located in western part of Kenya and lies in the Lake Victoria basin 150kilometers west of the great African Rift Valley. It measures approximately 19,649 hectares and lies in altitude that ranges between 1500m and 1600m above sea level and up to 2060m for a few scattered forested hills such as Lirhanda where termites were collected. Kalunya Glade which is a marshy clay swampy region that lies between 800-100m above sea level and ranging in size from about 1 to 50 hectares consisting of grassy glade (Mutangah *et al*., 1992). The Forest receives 2080mm rainfall annually and has a temperature range of between 11^{o}C and 26^{o}C (Kakamega District Development Plan, 1994). The soils are generally Acrisols of low fertility medium to heavy textured clay loams and

clay with Ph below 5.5 (FAO, 1989). Soil Feeding termites of *Cubitermes severus* species were collected from Kalunya Glade and Lirhanda hill in their respective mound and surrounding soil sampled one meter apart in three directions from the termite mound using a clean metal soil core with dimensions: 25 mm diameter and 100 mm depth.

2.1.2 Juja

Juja is located in lowland areas in the eastern parts of the Thika District. The District is located in the southern part of Central Province in the Kenya. It lies between latitudes 3° 35" and 1°45" south of the Equator and Longitudes 36º 35" and 37º 25" East (Thika District Development Plan, 2001). The climate of the area is generally semi arid and receives low rainfall of 856mm with a bimodal distribution. The area has an attitude of 1,060nm above sea level and mean annual temperature of 20ºC and the mean maximum temperature is 30ºC (Muchena *et al*., 1978).

There are three types of soil in Juja, these are Shallow clay soils (Murram) coded ppm, deep clay soils (Vertisols) coded ppd and Soil associations and complexes coded ppc, **(**Muchena *et al*., 1978). The vegetation has *Acacia- Themeda* and common grasses such as *Themeda triandra* (Muchena *et al.,* 1978). Samples of soil were randomly collected from the three types of soil commonly found in the area. Soil cores were collected from the soil types using a clean metal soil core with the following dimensions: 25mm diameter and 100mm depth. The soil core was transported to the laboratory in sealed polyethylene bag at room temperature. The upper 30mm of each core are discarded and large roots and stones removed from the remainder that is then sieved through a sterile brass sieve of 2-mm aperture size.

2.2 Cultivation

Dilute nutrient broth plus Agar (DNBA) media used for cultivation was prepared with 0.08 g of nutrient broth solidified with 15 g Bacto agar (Difco) (Janssen *et al*., 2002) at a pH of 6.23. Ten termites (0.18 g) were degutted using sterile fine-tipped forceps. The gut sections were pooled and homogenized in 1ml basal salt solution (Leadbetter and Breznak, 1996 and Mackenzie *et al.,* 2007). A gram of freshly sieved soil/ mound was added to 9 ml aliquots of sterile distilled water and the solution was agitated using a vortex mixer at approximately 150 rpm for five minutes. Serial dilutions from the gut, soil and mound suspension were carried out up to 10^{-6}. Spread plates were then prepared from 0.1 ml of dilutions 10^{-4} and 10^{-5} (Janssen *et al*., 2002). The samples were also subjected to dilution and heat shock method where the dilutions were first preheated in a hot water bath (50 ^{o}C) for six minutes before spreading 0.1 ml of dilutions 10^{-4} and 10^{-5} on to DNBA plates (Mincer *et al.,* 2002). Cultivation was done in triplicate and all the 162 plates were incubated in the dark at temperatures 25 ^{o}C, 30 ^{o}C and 37 ^{o}C for 2 weeks (Janssen *et al*., 2002). Isolates were selected based on colony morphology and those exhibiting zones of inhibition on the primary culture. They were labeled based on sample and temperature at which they grew. These isolates were purified in dilute nutrient broth plus agar media and stocked at $^{-}$80ºC.

2.3 Morphological and Biochemical Characterization of Isolates

Morphological characterization was performed using gram stain and isolates were observed under inverted microscope at ×100 oil immersion (Cappuccino and Sherman, 2002). Biochemical tests on these isolates were performed as follows: Primary and secondary screening for antibiotic producing isolates against the test organisms *Bacillus subtilis* (NCIB3610*), Escherichia coli* (NCTC 10418) and *Candida albicans* (CACBS 562); Screening for enzyme activity using starch, gelatin, casein and cellulose as substrates; Indole production test; Hydrogen sulfide production test; motility; Nitrate reduction test; Urease test; Catalase test; Ability of isolates to grow in 7% sodium chloride. Ability of the isolates to utilize the following substrates: arabinose, maltose, fructose, sucrose, lactose, mannitol, xylose and xylan. This was determined using 2% of the substrate added to a solution that consisted of Nacl (0.1%), K_2HPO_4 (0.1%), $MgSO_4$ (0.05%), $FeSO_4.7H_2O$ (0.001%), $CuSO_4.7H_2O$

(0.0001%), $ZnSO_4.7H_2O$ (0.0001%g), $MnSO_4.7H_2O$ (0.0001%). Substrate utilization was determined after incubation by measuring turbidity that indicated growth. Uninoculated control for each substrate was used as a standard when measuring turbidity using Spectrophotometer at 560 nm (Cappuccino and Sherman, 2002; Harold, 2002).

2.4 Molecular Characterization

Identification of isolates was done through sequencing of 16S ribosomal RNA gene. DNA extraction was performed in 16 isolates using a method described by Sambrook *et al*., 1989. DNA purification was performed using QIAquick PCR purification Kit protocol (Qiagen, Germany). DNA amplification of the 16S ribosomal RNA genes was done using the QIAquick PCR purification kit (Qiagen, Germany) and bacterial primer pair 27F forward 5'-AGA GTT TGA TCC TGG CTC AG-3' in relation to Escherichia coli positions 8 to 27 (Edwards *et al*., 1989) and 1492R reverse, 5'-TAC GGY TAC CTT GTT ACG ACT T-3' Escherichia coli positions 1492 to 1512 (Wesburg *et al.,* 1991). The 16S rRNA gene sequences were compared using BLAST (http://www.ncbi.nih.gov) to those in the Genebank database (Altschul *et al*., 1990; Shayne *et al*., 2003). The identification criteria used is as described by (Felsentein, 1989; Saitou and Nei, 1987).

3.0 Results

A total of one hundred and thirty seven pure isolates were obtained from fifteen samples that included soil, termite mound and termite gut. Screening for potential antibiotic production was performed as shown in Table 1 below.

Table 1: Sensitivity test of the active isolates on test organisms; B. subtilis E.coli, and C. albicans, using disc assay in cm

Sample	Isolate	*B.subtilis (NCIB3610)*	*E.coli (NCTC 10418)*	*C.albicans (CACBS 562)*
	Control	0.5	0.5	0.5
Juja soil asociation	84PPD30^{o}C	-	0.8	0.8c
Lirhanda B nest	29 LAN 30^{o}C	-	1.2	0.8
Lirhanda B Nest	57 LBN 30^{o}C	-	1.0	1.0
Lirhanda B nest	51 LBN 37^{o}C	-	1.0	1.1
Surrounding soil kalunya B	7 SKB 30^{o}C	0.9	1.0	1.1
Surrounding soil Lirhanda A	14 SLA 30^{o}C	0.8	0.8	-
Kalunya gut A	14 KAG 30^{o}C	0.8	-	-
Kalunya gut A	63KAG 25^{o}C	1.0	0.8	-
Lirhanda B Nest	24 LBN 30^{o}C	1.1	0.9	0.8
Surrounding soil Kalunya A	1 SKA 37^{o}C	0.8	0.8	0.8
Lirhanda gut B	62 LBG 37^{o}C	1.0	0.8	-
Murrum soil	142 M(b) 30^{o}C	1.0	0.7	-
Surrounding soil Lirhanda A	58 SLA 25 ^{o}C	1.0	1.0	-
Surrounding soil kalunya B	11 SKB 30^{o}C	1.0	1.0	0.9
Surrounding soil kalunya B	9 SKB 25^{o}C	1.0	-	1
Murrum soil	142 M 30^{o}C	-	-	-
Lirhanda gut B	1 1LBG 25^{o}C	0.7	-	0.7
Lirhanda B nest	LBN37^{o}C	0.8	0.7	0.8
Lirhanda gut B	LBG30^{o}C	0.7	-	0.7
Kalunya gut A	4KAG30^{o}C	0.7	-	0.7

Antimicrobial activity results for the 20 isolates (+) a positive result for the reaction and (-) a negative test for the reaction.

Ninety two (92) isolates were also screened for amylases, caseinases, gelatinases and cellulases. The percentage distribution of enzyme producing bacteria in the sample units was studied and summarized as follows: Sixty five percent (65%) of all isolates were starch degraders, Fifty four percent (54%) of the isolates degraded casein, sixty eight percent (68%) of the isolates degraded gelatin and Cellulose was degraded by 11% of the isolates obtained from termite gut. In addition 7% of isolates obtained from mound were cellulose degraders. The enzymatic activities of twenty (20) isolates whose antimicrobial activities were investigated in table 1 and characterized through biochemical tests (Table 3) are as shown in table 2 below.

Table2: Enzymatic activities of isolates

Isolate	Amylases	Caseinases	Gelatinases	Cellulases
84PPD30^{o}C	+	-	+	-
29 LAN 30^{o}C	+	-	+	-
57 LBN 30^{o}C	-	+	+	-
51 LBN 37^{o}C	-	+	+	-
7 SKB 30^{o}C	+	-	+	-
14 SLA 30^{o}C	+	+	+	-
14 KAG 30^{o}C	+	-	+	-
63KAG 25^{o}C	+	-	+	-
24 LBN 30^{o}C	+	-	+	-
1 SKA 37^{o}C	+	-	+	-
62 LBG 37^{o}C	+	-	+	-
142 M(b) 30^{o}C	+	-	+	-
58 SLA 25^{o}C	+	+	+	-
11 SKB 30^{o}C	+	+	-	+
9 SKB 25^{o}C	-	+	+	-
142 M 30 ^{o}C	+	+	+	-
1 1LBG 25^{o}C	-	+	+	-
2LBN37^{o}C	+	+	+	+
3LBG30^{o}C	+	+	+	+
4KAG30^{o}C	+	+	+	-

Enzymatic activity results for the 20 isolates (+) a positive result for the reaction and (-) a negative result for the reaction

Table 3: showing biochemical test of 20 isolates that were under investigation

ISOLATE	NIT	URE	XYL	IND	MAN	ARA	MAL	FRU	SUC	LAC	NCL7%	XY
24LBN30^{o}C	+	-	nd	-	nd	+	+	+	+	-	nd	nd
1 SKA37 ^{o}C	+	-	nd	-	nd	+	-	+	+	-	nd	nd
62LBG37^{o}C	+	-	nd	-	nd	+	-	+	+	-	nd	nd
63KAG37^{o}C	+	-	nd	-	nd	+	+	+	+	-	nd	nd
58SLA25^{o}C	+	-	nd	-	nd	+	+	+	+	-	nd	nd
14KAG30 ^{o}C	+	-	nd	-	nd	+	-	+	+	-	nd	nd
14SLA30 ^{o}C	+	-	nd	-	nd	+	-	+	+	-	nd	nd
142MB30 ^{o}C	+	-	nd	-	nd	+	-	+	+	-	nd	nd
142M30 ^{o}C	+	+	nd	+	nd	-	-	-	-	+	nd	nd
51LBN37 ^{o}C	+	+	nd	+	nd	-	+	+	-	-	nd	nd
57LAN30 ^{o}C	+	+	nd	+	nd	-	+	+	-	-	nd	nd

29LAN30 °C	+	+	nd	+	nd	-	+	+	-	-	nd	nd
11SKB30 °C	+	-	+	-	+	-	+	+	+	+	+	nd
84PPD30 °C	-	-	nd	+	nd	-	+	+	+	-	nd	nd
7SKB30 °C	-	-	nd	+	nd	+	+	+	+	-	nd	nd
9SKB 25 °C	+	+	nd	-	nd	-	-	+	+	+	nd	nd
1LBG25 °C	-	-	+	-	+	nd	nd	nd	+	nd	+	-
2LBN37 °C	-	+	-	-	-	nd	nd	nd	-	nd	+	-
3KAG 0 °C	+	+	+	-	-	nd	nd	nd	-	nd	+	-
4LBG30 °C	+	+	+	-	+	nd	nd	nd	+	nd	+	+

Biochemical test result for 20 isolates (+) positive reaction,(-) negative reaction and (nd) not determined.NIT-nitrates,URE-ureas,XYL-xylose,IND-indole,MAN-mannitol,ARA-D arabinose,MAL-maltose,FRU-fructose,SUC-sucrose,LAC-lactose,NCL7%-sodium chloride,XY-xylan

3.1 Morphological Characterization of Isolates

Morphological studies of the isolates was done using the dissecting (×16) and light microscopes (×100 oil immersion). Majority of the isolates obtained were rod shaped gram positive bacteria as shown in Table 4.

Table 4: Morphological characteristics of isolates

Isolate	Gram	Cell shape	endospore	Colony morph.	color	Pigment	Motility
24 LBN30 °C	+	Rod	+	Circular ,slightly raised , entire	Cream white	-	+
1 SKA 37 °C	+	Rod	+	Circular ,slightly raised , entire	Cream white	-	+
62 LBG37 °C	+	Rod	+	Circular, slightly raised, entire	Cream white	-	+
63KAG 37 °C	+	Rod	+	Circular ,slightly raised ,entire	Cream white	-	+
58SLA25 °C	+	Rod	+	Circular ,slightly raised ,entire	Cream white	-	+
14KAG30 °C	+	Rod	+	Circular ,slightly raised entire	Cream white	-	+
14SLA30 °C	+	Rod	+	Circular ,slightly raised ,entire	Cream white	-	+
142MB30 °C	+	Rod	+	Circular ,slightly raised , entire	Cream white	-	+
142M30 °C	-	Rod	-	Circular, serrate flat	Cream white	Green	+
51LBN37 °C	+	Rod	+	Circular, mucoid. convex,	Cream white	-	+
57LAN30 °C	+	Rod	+	Circular, mucoid. convex,	Cream white	-	+
29LAN30 °C	+	Rod	+	Circular, mucoid. convex,	Cream white	-	+
11SKB30 °C	+	short rod	-	Circular,entire,convex	Cream white	-	-
84PPD30 °C	+	Rod	+	Circular, mucoid. convex,	cream white	-	+
7SKB30 °C	+	Rod	+	Circular entire, raised	Cream	-	+

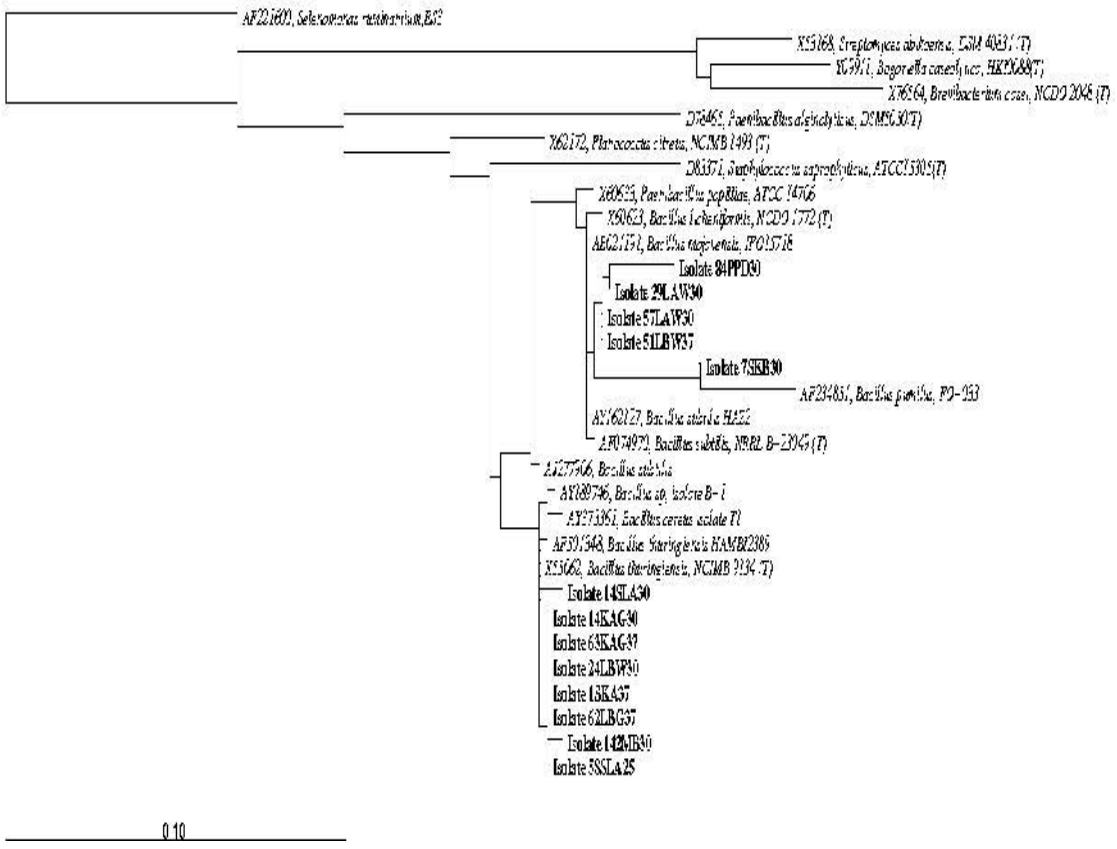
9SKB 25 °C	-	Coccid rod	-	Circular, slightly raised	entire	pink	pink	+

Morphological test for the 16 isolates (+) a positive result or presence and (-) a negative result /no presence. Colony morph.-colony morphology .

3.2 Phylogenetic Cluster Analysis of Sequences

The 16SrRNA gene amplified products from sixteen isolates (Table 7) were successfully sequenced. Phylogenic analysis using BLAST software (http://www.ncbi.nih.gov) showed that they belong to the domain Bacteria and phyla *Firmicutes, Proteobacteria and Actinobacteria.* Thirteen isolates were clustered with the low G+C content *Firmicutes* in to three clusters: Isolates 1SKA37°C, 58SLA25°C, 142MB30°C, 14SLA30°C 14KAG30°C, 62LBG37°C, 63KAG37°C and 24LBN30°C all clustered with *Bacillus thuringiensis*. It was supported with a sequence similarity of 99.3%-99.7% and bootstrap value of 99%. On the other hand isolates 51LBN37°C and 57LBN37°C from termite nest were clustered with *Bacillus mojavensis* with a sequence similarity of 99.7% and bootstrap value of 99%. Isolate 29LAN 30 °C and 84PPD30 °C were clustered with *Bacillus subtilis* and respectively with a sequence similarity of 99.5% and bootstrap value of 99%. Lastly, isolate 7SKB 30 °C from soil was clustered with *Bacillus pumilus* with a sequence similarity of 99.33% and bootstrap value of 99% as shown in Figure 1 below.

Figure 1: Phylogenetic tree showing positions of isolates closely related to *Firmicutes*. The scale bar indicates approximately 10% sequence difference. Included are sequences from termite gut, mound and soil. 1SKA37°C, 58SLA25°C142MB30°C, 14SLA30°C, 14KAG30°C, 62LBG37°C), 63KAG37°C, 24LBN30°C, 51LBN37°C57LBN37°C, 29LAN30°C, 84PPD30°C, 7SKB30°C



The second phylum that was represented in the phylogenetic analysis was the *Actinobacteria* phylum. Isolate 11SKB 30^{o}C was clustered with *Brachybacterium paraconglomeratum* (Figure 2) with a sequence similarity of 100% and bootstrap value of 99% in the Genbank database.

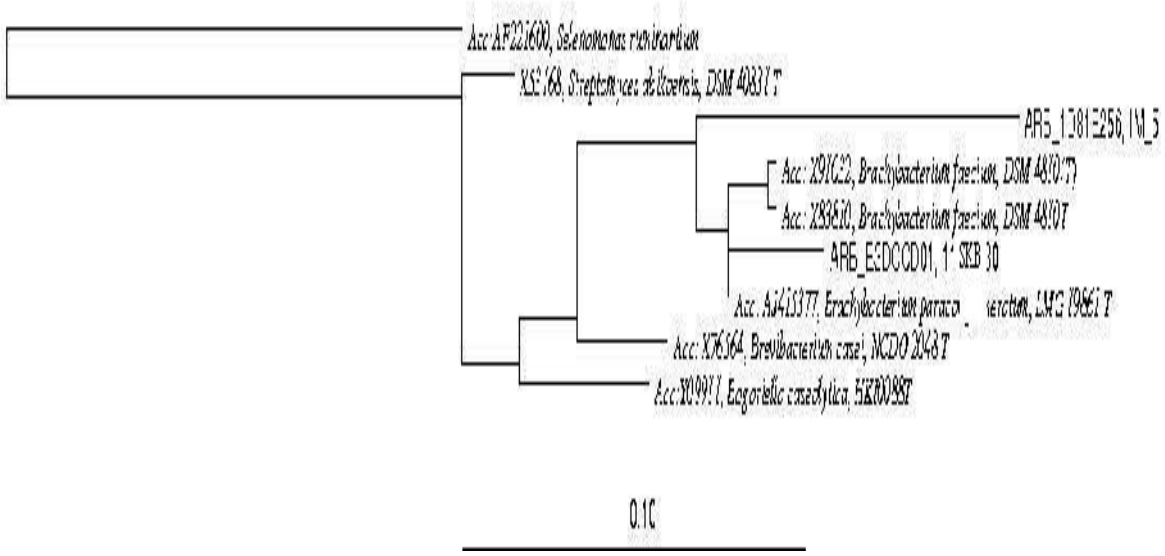


Figure 2: Phylogenetic tree showing positions of isolates closely related to Actinobacteria phyla. The scale bar indicates approximately 10% sequence difference. Included are sequences from isolate 11SKB 30^{o}C

The third phylum represented in the phylogenetic analysis of isolates was the *Proteobacteria* phylum. Isolate 142M30^{o}C was clustered with *Pseudomonas aeruginosa* (Figure 3) with a sequence similarity of 99% and bootstrap value of 98% in the Genbank database. The phylum *Proteobacteria* phylum was also represented by isolate 9SKB 25^{o}C clustered with *Serratia marcescens* (Figure 3) with a sequence similarity of 99.4% and bootstrap value of 98%. The species *Serratia marcescens* belongs to the family Enterobacteriacea.

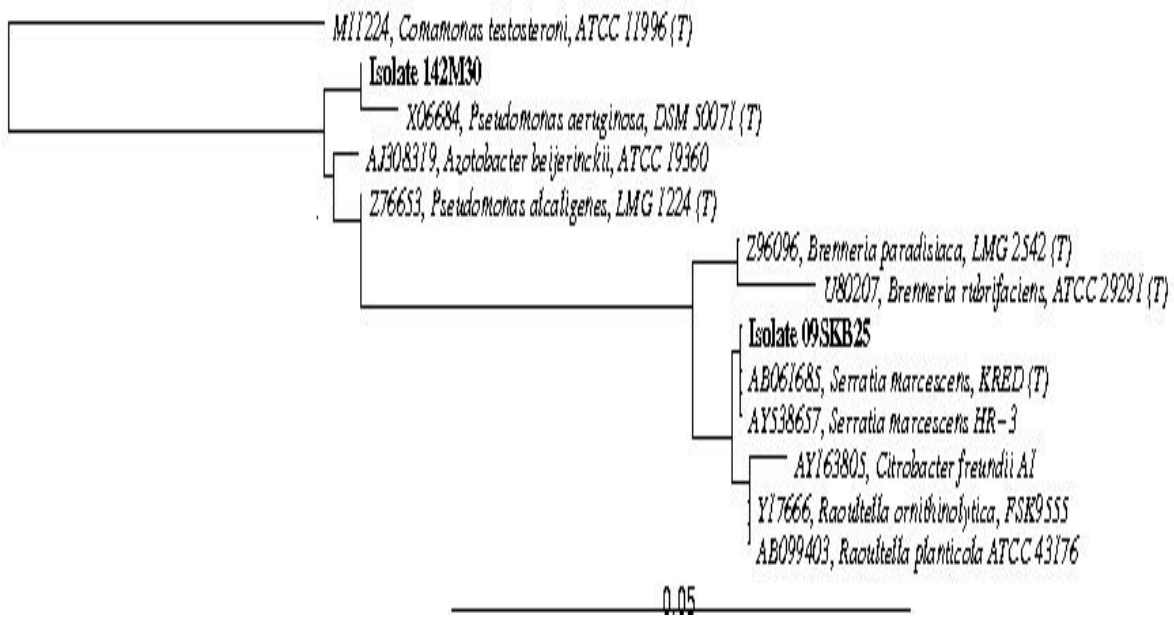


Figure 3: Phylogenetic tree showing positions of isolates closely related to proteobacteria phyla. The scale bar indicates approximately 50% sequence difference. Included are sequences from soil isolates 142M30^{o}C and 9SKB 25^{o}C

4.0 Discussion

The media (DNBA) used in this study was favorable as it allowed the development of a wide range of bacteria present in the sample, prevented growth of spreading colonies and allowed the least possible growth of unwanted non-bacterial colonies such as fungi (Janssen *et al*., 2002).

The study showed majority of isolates were gram positive bacteria and few gram negative (Table 4). Previous studies had shown that enteric bacteria have difficulty competing with natural micro flora for the low concentration of available nutrients in natural ecosystems (Burton *et al.,* 1987). Instead the enteric bacteria have grown with much ease in most standard nutrient rich laboratory media preventing growth of the majority micro flora found in natural ecosystems. In this study there were few enteric bacteria (Figure 3) as a result of low nutrient media used.

Prokaryotic microorganisms have been previously shown to inhabit the gut of soil feeding termites (Brune, 1998; Brauman *et al*., 2000). Previous analysis of soil feeding termite gut using PCR-denaturing gradient gel electrophoresis (DGGE) revealed presence of *Firmicutes* phyla in the termite gut library (Fall *et al.,* 2007). Morphological characterisation in this study showed majority of termite gut isolates were Gram positive-rod shaped, endospore forming and motile bacteria (Table 4). Phylogenetic analysis showed that these isolates were closely related to members in the bacillus group (Figure 2). Through biochemical characterisation (Table 3), these isolates showed ability to reduce nitrates to nitrites and nitrogen supporting the hypothesis that nitrogenous components of humus are an important dietary resource for humivorous soil macro invertebrates (Ji *et al.,* 2000; Ji and Brune, 2001).

Phylogenetic analysis of isolates also revealed members closely related to the bacilli group in the termite mound and surrounding soil (Figure 1). Previous analysis of soil feeding termite mound using PCR- denaturing gradient gel electrophoresis (DGGE) revealed presence of *Firmicutes* phyla in the termite mound and surrounding soil library but to a lesser extent when compared to those found in the gut samples (Fall *et al.,* 2007). Biochemical characterisation showed that these isolates (Bacilli group) were nitrate and nitrites reducers (Table 3) indicating the role these isolates play in the nitrogen cycle of termite mound, gut and soil (Collins, 1983**).**

Previous studies have shown presence of isolates able to utilize glucose (Boga *et al*., 2007). In this study the isolates were able to utilize arabinose, maltose, sucrose and fructose (Table 3) an indication of the role played by these isolates in the formation of short chain fatty acids from carbohydrates or synthesis of amino acids (Cummings and Macfarlane, 1997).

Isolates whose sequences were closely related to *Serratia marcescens* and *Pseudomonas aeruginosa* were obtained from surrounding soil and Juja soil samples respectively (Figure 3). Morphological characterisation revealed the isolates were Gram negative, rod-shaped and motile (Table 4) bacteria belonging to *Proteobacteria,* phylum (Bergy's manual, 1989). Previous analysis of soil feeding termite surrounding soil using PCR- denaturing gradient gel electrophoresis (DGGE) revealed the presence of *Proteobacteria* phylum in the surrounding soil library (Fall *et al.,* 2007) hence this study was able to cultivate them in low nutrient media. Biochemical characterisation of the isolate closely related to *Serratia marcescens* revealed ability to utilize fructose, sucrose and lactose (Table 3). These isolates were also able to reduce nitrate (Table 3) indicating the role it could play in the nitrogen cycle (Lengeler *et al*., 1999) in its habitat.

Phylogenetic analysis further revealed an isolate closely related to *Brachybacterium paraconglomeratum* (Figure 3) obtained in the surrounding soils of termite gut. Previous analysis of soil feeding termite surrounding soil using PCR- denaturing gradient gel electrophoresis (DGGE) revealed presence of members of Dermabacteraceae family in the nearly half of the surrounding soil clone library (Fall *et al*., 2007). This *Brachybacterium* species belongs to the Dermabacteraceae family and *Actinobacteria* phylum (Stackebrandt, 1997). It is a Gram positive, coccid-rod shaped, non spore forming non motile (Table 4) and high G+C content bacteria (Takeuchi *et al.,* 1995). The ability of this isolate to reduce nitrate indicates the role it plays in the nitrogen cycle (Lengeler *et al*., 1999). Substrate utilisation tests of the isolate revealed the ability to utilize lactose, xylose, mannose, fructose, galactose, maltose and sucrose (Takeuchi *et al.,* 1995).

Potential antibiotic producers in termite gut and mound samples were clearly shown in this study (Table 1). This is consistent with previous studies that showed the *Bacillus* species are capable of producing antibiotic as secondary metabolites (Katz and Demau, 1977). Isolate 11SKB 30^{o}C obtained from surrounding soil that was closely related to *Brachybacterium* species was capable of producing antagonistic effects against the test organisms (Table 1). *Brachybacterium* species has been used in previous studies to eliminate *Staphylococcus aureus* (Takeuchi *et al.,* 1995)

Members of genus *Bacillus* are capable of secreting a wide variety of enzymes such as amylases and proteases (Priest 1977; Mezes and Lampen, 1985). In this study, isolates obtained from termite gut closely related to *Bacillus* species had the ability to degrade starch, an indication of the role the amylases play in extracting organic matter from the soil in the gut, a process that is favoured by alkaline conditions in the gut (Brune, 1998; Kappler and Brune, 1999). The termite gut isolates capable of degrading gelatin (Table 2) is in line with previous studies that have shown presence of aerobic organisms in the gut capable of degrading gelatin (Boga *et al*.,2007). In addition isolates in termite mound and surrounding soil respectively were able to degrade gelatin (Table 2). Gelatin degrading isolates (Table 2) were closely related to members of Genus *Bacillus* (Figure 1) in line with

previous investigations by Debabor (1982). Isolate 11SKB 30^{o}C thats closely related to *Brachybacterium* species (Figure 2) was aslo able to degrade gelatin in line with previuos investigations by Takeuchi *et al.,* (1995) an indication of the role they play in transformation of peptides and protein in their habitat.

Brune and his co-workers were able to show that soil-feeding termites transform cellulose in the soil an indication of presence of cellulolytic bacteria in the gut (Ji and Brune, 2001). In this study, there were termite gut and mound isolates capable of degrading cellulose indicating the role played by these bacterial isolates in degrading cellulotic materials in termite mound (Table 2). The Ability of the majority of isolates from soil, gut and mound to utilize various sugars (Table 3) is an indication of the role they play in generation of short chain fatty acids from carbohydrates (Cummings and Macfarlane, 1997).

5.0 Conclusions

The study has demonstrated using low nutrient media (DNBA) in cultivation, the isolation and characterization of bacterial isolates in the termite gut, mound and soil and further shown that these samples are a potential source of antibiotic and enzyme producing bacteria.

6.0 Recommendation

To get a clear insight into the mechanism of antagonism, further studies should be done to characterize and identify the proteins or compounds with antimicrobial activity.

Acknowledgements

This work was supported by Research grant from Jomo Kenyatta university of Agriculture and Technology Research Production and Extension Division.

References

Altschul, S. F., Gish, W. Miller, E. W. Myers and lipman, D. J. (1990). Basic local alignment search tool. *Journal of Molecular Biology,* **215**, pp 403-410.

Atlas, R. M., (1984). Diversity of Microbial Communities volume 7 New York Plenum Press.

Bergy's manual, (1989) of systematic bacteriology, volume 4, eds. S.T.Williams and M.E.Sharpe, Baltimore, Md: Williams and Williams.

Bignell, D. E., H. Oskarsson and J. M. Anderson, (1980). Distribution and abundance of bacteria in the gut of a soil–feeding termite Procubitermes aburiensis (Termitidae, Termitinae). *Journal of General Microbiology,* **117**, Pp 393–403.

Boga, H. I., Ji, Ludwig, R. W. and Brune, A. (2007). *Sporotaela propionica* genera novel species. Hydrogen oxidizing, Oxygen reducing, propiogenic firmicutes from the intestinal tract of a soil feeding termite. *Archives of Microbiology,* **187** (1), pp 15-27.

Brauman, A., Bignell, D. E. and Tayasu, I. (2000). Soil–feeding termites: biology, microbial associations and digestive mechanisms *In:* T. Abe, D. E. Bignell, and M. Higashi (eds.) Termites: evolution, sociality, symbiosis, ecology. Kluwer Academic Publishers, Dordrecht. Pp 233–259

Brauman, A., Dore, J., Eggleton, P., Bignell, D., Breznak, J. A. and Kane, M. D. (2001). Molecular phylogenetic profiling of prokaryotic communities in guts of termites with different feeding habits. *FEMS Microbiology Ecology,* **35**, pp 27–36.

Brune, A., (1998). Termite guts: the world's smallest bioreactors. *Trends in Biotechnology*, **16**. Pp 16–21.

Burton, G.A., D. Gumison, and G. R. Lanza, (1987). Survival of pathogenic bacteria in various fresh water sediments. *Applied and Environmental Microbiology* **53**, pp 633-638.

Button, D. K., Schunt, F., Quang, P., Martin, R. and Robertson, B. R. (1993). Viability and isolation of typical marine oligotrophic bacteria by dilution culture theory, procedures and initial results. *Applied and Environmental Microbiology*, **59**, pp 881-891.

Cappuccino, J. G. and Sherman, N. (2002). Microbiology. A laboratory manual. 6th edition. Pearson education inc. San Francisco, California, pp 215-224

Claus, D. and Berkeley, R. C. W. (1986). Genus *Bacillus* Cohn 1872, (2)1105-1139. **In**: P.H.A. Sneath, (eds.), Bergey's Manual of Systematic Bacteriology, Volume 2. Williams and Wilkins Co., Baltimore, MD.

Collins, N. M., (1983). The utilization of nitrogen resources by termites (Isoptera) In: J. A. Lee, S. McNeill, and I. C. H. Rorison (eds.) Nitrogen as an Ecological Factor. Blackwell Scientific Publications, Oxford, pp 381–412.

Collins, N. M. and T. G. Wood, (1984). Termites and atmospheric gas production. *Science* **224**, pp 84–86.

Cummings, J. H. and MacFarlane, G. H. (1997). Role of intestinal bacteria in nutrient metabolism. *J Parenter Enteral Nutr.,* **21**, pp 357-365.

Debabor, V. G., (1982). The industrial use of bacilli 331-370. D.A. Dubnau (eds). The molecular biology of the bacilli. Academic press .New York.

Embley, M. T. and E. Stackebrandt, (1996). Molecular Approaches to Environmental microbiology (Editors. pickup, R.w. and Saunders J.R.), Prentice Hall, United Kingdom, pp 39-62.

Fall, S., Hawelin, J. Ndiaye, F., Assigbetse, K., Aragno, M. Chotte J. L. and Brauman, A. (2007). Differences between Bacterial Communities in the gut of a soil feeding termite (*Cubitermes niokoloensis*) and its mound. *Applied and Environmental Microbiology,* **73**(16), pp 5199-5208.

FAO(Soil reference) 1989 Food and Food security .FAO Forestry paper, FAO (UN), **90**, pp1-2.

Felsentein, J., (1989). PHYLIP--phylogeny interference package (version 3.2). *Cladistics,* **5**, pp 164-166.

Government of Kenya, (1994). Kakamega District Development Plan 1994-1996. Office of the Vice President and Ministry of Planning and National Development.

Government of Kenya, 1997. Thika District Development Plan 1997-2001 Office of the Vice President and Ministry of Planning and National Development.

Grass'e, P. P., (1984). Terminology Foundation Dessocietes-Construction Volume 2 Masson Paris France.

Holt, J. A. and Lepage, M. (2000). Termites and soil properties 389-407. In T. Abe. D.E Bignell and M. Higashi (eds), Termites evolution, sociality, symbioses, ecology, Volume 1 Kluwer Academic, Dordrecht. Netherlands.

Janssen, P. H., Yates, P. S., Grinton, E. B., Taylor, P.M. and Sait, M. (2002). Improved culturability of soil Bacteria and isolation in Pure culture of novel members of the division Acidobacteria, Actinobacteria, Proteobacteria and Verrucomicrobia. *Applied and Environmental Microbiology*, **68**, pp 2391-2396.

Ji R., A. Kappler and A. Brune, (2000). Transformation and mineralization of synthetic ^{14}C–labeled humic model compounds by soil–feeding termites. *Soil Biology and Biochemistry,* **32,** pp 1281– 1291.

Ji, R., and A. Brune, (2001). Transformation and mineralization of 14 C-labeled cellulose, peptidoglycan. *Soil Biology and Biochemistry,* **32**, pp 1281–1291.

Kappler, A. and Brune, A. (1999). Influence of gut alkalinity and oxygen status onmobilization and size–class distribution of humic acids in the hindgut of soil–feeding termites. *Applied and Soil Ecology*, **13**, pp 219–229.

Katz, E. A. and L. Demari, (1977). Tripeptide antibiotics of Bacillus; Chemistry, Biogenesis and possible functions Bacterial Review, **41**, pp 449-474.

Leadbetter, J. R. and J. A. Breznak, (1996). Physiological ecology of *Methanobrevibacter cuticularis* species novel and *Methanobrevibacter curvatus* species novel isolated from the hindgut of the termite *Reticulitermes flavipes*. *Applied and Environmental Microbiology,* **62**, pp 3620-3631.

Lee, K. E. and T. G. Wood, (1971). Termites and Soils, Academic Press New York.

Lengeler, J. W., G Drews and H.G. Schlegel. 1999. Biology of the Prokaryotes. Blackwell Scientific. Malden.MA.

Liesack, W., Janssen, P. H., Rainey, F. A., ward-Rainey, N. L. and Stackebrandt, E. (1997). Microbial diversity in soil: The need for a combined approach using molecular and cultivation Techniques. In modern soil Microbiology. Elsas, J.D., Trevors, J. T. and Wellington E. M. H (Editors) New York: Marcel Dekker, pp 375-439.

Mackenzie, L. M., A. T. Muigai, E. O. Osir, W. Lwande, M. Keller, G. Toledo and H. I. Boga, (2007). Bacterial Diversity in the intestinal tract of the Fungus Cultivating termite *Macrotermes michaelseni. African Journal of Biotechnology*, **6**(6), pp 658-667.

Mezes, P. S. and J. O. Lampen, (1985). Secretion of proteins by Bacillus 151-185. D.A. Dubnau (ed). The molecular biology of the bacillus, Volume 2. Academic Press,New York.

Mincer, T. J., P. R. Jensen, C. A. Kauffman and W. Fanical 2002. Widespread and persistent populations of a major new marine Actinomycete taxon in ocean sediments. *Applied and Environmental Microbiology,* **68**, pp 5005–5011.

Muchena, F. N., W. M. Wamich, C. R. K. Njoroge, (1978). Detailed Soil Survey of Jomo Kenyatta University of Agriculture and Technology (Juja) (Kiambu District) Ministry of Agriculture-National Agricultural Laboratories Nairobi 1-25.

Mutangah, J. G., O. M. Mwangangi and P. K. Mwaure, (1992). Kakamega Forest Vegetation survey. Kenya indigenous Forest Conservation Program National Museum of Kenya 248-259.

Noirot, C., (1992). From wood– to humus–feeding: an important trend in termite evolution. In: Biology and Evolution of Social Insects (Billen, J., ed) 107–119. Leuven University Press, Leuven, Belgium.

Nutting, W. L., (1990). Insecta Isoptera .**In**: Dindal, D. L. (Eds) Soil Biology Guide. John Wiley and Sons, New York 997-1032.

O'Donnnell, A. G., M. Seasman, A. N. Macne, T. Davies, (2001). Plants and fertilizers as drivers of change in Microbial Community Structure and Function in soil. *Plant soil,* **232**, pp 135-145.

Priest, F. G., (1977). Extra cellular enzymes synthesis in the genus *Bacillus* Bacterial. Review **41**, pp 711-753.

Rolf, D., (2004). The soil metagenome as a rich resource for the discovery of natural products. *Current Opinion in Biotechnology,* **15**. Pp 199-204

Rouland, C., A. Brauman, M. Labat and M. Lepage, (1993). Nutritional factors affecting methane emission from termites. Chemosphere **26**, pp 617–622.

Saitou, N. and M. Nei, (1987). The neighbor-joining method. A new method for reconstructing phylogenetic trees. Molecular Biology. *Evolution*, **4**, pp 406-425.

Sambrook, J., E. F. Fritsch and T. Maniatis, (1989). Molecular cloning: a laboratory manual, 2nd edition Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York.

Schmitt–Wagner, D., M. W. Friedrich, B. Wagner and A. Brune (2003a). Phylogenetic diversity, abundance, and axial distribution of bacteria in the intestinal tract of two soil–feeding termites *(Cubitermes* species). *Applied and Environmental Microbiology,* **69**, pp 6007–6017.

Shayne, J. J., P. Hugenholtz, P. Sangwan, C. Osborne and H. P. Janssen, (2003). Laboratory cultivation of widespread and previously uncultured soil bacteria. *Applied and Environmental microbiology*, **69**, pp 7211-7214.

Stackebrandt, E., F.A. Rainey and N.L. Ward-Rainey, (1997). Proposal for new Hierarchic Classification System, Actinobacteria classics Novel. *International Journal for Systemic Bacteriology,* **47**, pp 479-491.

Stevenson, B. S., A. Stephanie, J. Fichorst, T. Wertz, T. M. Schmidt and J. A. Breznak, (2004). New strategies for cultivation and detection of previously uncultured microbes. *Applied and Environmental Microbiology,* **70**(8), pp 4748-4755.

Strohl, W. R., (2000). The Role of natural products in modern drug discovery. *Drug Discovery Today* **5**, pp 39-41.

Takeuchi, M. and Fang, C. X. (1995). Taxonomic study of the genus *Brachybacterium*: proposal of *Brachybacterium conglomeratum* sp. Nov., nom. rev., *Brachybacterium paraconglomeratum* sp. Nov., and *Brachybacterium rhamnosum* sp. nov. *International Journal of Systemic Bacteriology*, **45**, pp 160-168.

Talaro, A. and K. Talaro, (1996). Drugs microbe Host. The elements of Chemotherapy in foundations in Microbiology W.M., Brown: New York.

Tayasu, I., A. Sugimoto, E. Wada and T. Abe, 1994. Xylophagous termites depending on atmospheric nitrogen. *Naturwissenschaften,* **81**, pp 229–231.

Thomas, S. B. and E. Lewis, (1957). Some Biochemical Characteristics of Freshly isolated strains of the Genus Serratia. *Journal of Applied Bacteriology,* **20**(1), pp 11-16.

Torsvik V., F.L Daa, R.A. Sandaa and L. Orneas, 2002. Microbial diversity and function in soil: From genes to Ecosystems. *Current Opinion in Microbiology*, **5**, pp 240-245.

Weisburg, W.G., S. M. Barns, D. A. Pelletier and D.J. Lane, 1991. 16S ribosomal DNA amplification for phylogenetic study. *Journal of Bacteriology*, **173**, pp 697-703.

Wood, T. G. and R. A. Johnson, (1986). The biology, physiology, and ecology of termites In: Economic impact and control of social insects (Vinson, S. B., Ed.). 1–68. Praeger, New York.

Zengler, K., G. Toledo, M. Rappé, J. Elkins, E. J., Mathur, J. M. Short and M. Keller,(2002). Cultivating the uncultured. National academy of science USA, 99:15681- 115686.

SUB-THEME II

ADVANCES AND CHALLENGES IN HEALTH SCIENCES

AMINOGLYCOSIDE MODIFYING ENZYMES DETECTED IN STRAINS OF *ESCHERICHIA*, *KLEBSIELLA*, *PSEUDOMONAS* AND *ACINETOBACTER* IMPLICATED IN INVASIVE INFECTIONS IN NAIROBI, KENYA

D. W. Ndegwa, N. L. M. Budambula, S. Kariuki, G. Revathi, J. N. Kiiru
Institute of Biotechnology, Jomo Kenyatta University of Agriculture and Technology, Nairobi
Department of Botany, Jomo Kenyatta University of Agriculture and Technology, Nairobi
Centre for Microbiology Research, Kenya Medical Research Institute, Nairobi, Kenya
Microbiology Department, Aga Khan University Hospital, Nairobi
Centre for Microbiology Research, Kenya Medical Research Institute, Nairobi, Kenya
E-mail: nbudambula@yahoo.com

Abstract
Aminoglycoside resistance through the production of aminoglycoside modifying enzymes (AMEs) is common and thus of clinical importance. The presence of AMEs genes in gram-negative bacteria on plasmids, transposons and integrons facilitates the rapid acquisition of antibiotic resistance. This study aimed to characterize AMEs in antibiotic resistant strains of *Escherichia, Klebsiella, Pseudomonas* and *Acinetobacter* implicated in invasive infections in Nairobi, Kenya. The experimental design was a two point cross-sectional design comparing 54 clinical isolates obtained from the KEMRI laboratory collected in 2001 to 2006 and 54 clinical isolates from Aga Khan University Hospital collected in 2007 to 2008. The isolates were identified, tested for antimicrobial susceptibility to seven aminoglycosides then the AMEs were detected phenotypically and genotypically. The most prevalent AME gene detected was *acc(6)-Ib-cr* (45.9%) followed by *acc(3)-II* (25.9%, *aac(6)-I*(22.2%) and *aac(3)-I* (16.3%). Phenotypic studies showed that multidrug resistant *Pseudomonas aeruginosa* harboured numerous AMEs and 81% of the resistance was conferred by impermeability. Increase in aminoglycoside resistance by both naturally derived and semi synthetic antibiotics is alarming. Methods for monitoring their effectiveness should be instituted at the different healthcare system in Kenya.

Key words: Aminoglycoside, antibiotic resistance, aminoglycoside –modifying enzymes (AMEs)

1.0 Introduction

Aminoglycosides are a group of antibiotics that are characterized by the presence of an aminocyclitol ring linked to amino-sugars in their structure. They are particularly active against aerobic and facultative aerobic Gram-negative bacteria including members of family *Enterobacteriaceae*, *Acinetobacter, Pseudomonas* and *Enterobacter* species. They are most frequently used for treatment of invasive infections such as septicaemia, complicated intra-abdominal infections, complicated urinary tract infections, and nosocomial respiratory tract infections (Mingeot-Leclercq *et al.,* 1999). The resistance of clinical isolates to aminoglycoside antibiotics varies with the specific drug, the microorganism, its mechanism of resistance, the geographic area and many other factors (Vakulenko and Mobashery, 2003).

There are four mechanisms of aminoglycoside resistance; reduced uptake or decreased cell permeability, alteration of the ribosomal binding site by mutation expression of rRNA methylases and production of aminoglycoside-modifying enzymes (AMEs). It is noteworthy that more than one mechanism may be at play at the same given time in a bacterium in the case of some classes of drugs (Vakulenko and Mobashery, 2003; Shakil *et al.,* 2008). Production of AMEs is the most common mechanism of Aminoglycoside Resistance and thus of most clinical importance. The three families of enzymes: Aminoglycoside Acetyltransferases (AACs), Aminoglycoside Nucleotidyltransferases (ANTs) and Aminoglycoside Phosphotransferases (APTs) perform co-factor dependent drug modification in the bacterial cytoplasm. Modified aminoglycosides bind poorly to the ribosome and fail to trigger energy-dependent phase II allowing the bacteria to survive in the presence of the drug (Shaw *et al.,* 1993).

Aminoglycoside resistance genes are derived from bacterial genes which encode enzymes involved in normal cellular metabolism. There are over 50 different AMEs that have been identified and enzymatic modification results in high-level resistance. The level of resistance produced differs significantly in various microorganisms and individual strains and depends on many factors, including the amount of enzyme produced, its catalytic efficiency, and the type of aminoglycoside (Mingeot-Leclercq *et al.,* 1999; Vakulenko and Mobashery, 2003).

In Kenya, there is scarcityof data on aminoglycoside resistance in invasive infections although they form the mainstay drugs in our hospitals for treatment of serious nosocomial infections by *Acinetobacter* spp., *Pseudomonas aeruginosa*, and ESBL- producing *Enterobacteriaceae*. The aim of this study was to characterize Aminoglycoside resistant strains of *Escherichia*, *Klebsiella*, *Pseudomonas* and *Acinetobacter* implicated in invasive infections in Nairobi, Kenya.

2.0 Materials and Methods

The study was two point cross-sectional comparing old stored and new isolates. The stored isolates were obtained from Kenya Medical research Institute (KEMRI) laboratory and were collected during the period of 2001-2006 from two hospitals, Kenyatta National Hospital (KNH- old) and Aga Khan University Hospital (AKUH-old). New isolates were collected from Aga Khan University Hospital (AKUH-new) in 2007-2008. The sample size was determined using the Fisher *et al.* (1925) formula. A total sample size of 108 was determined where; 41 samples were *E. coli*, 35 *Klebsiella*, 21 *P. aeruginosa* and 11 *A. baumannii.* Specimen sources included; Intravenous blood, urine, sputum, tracheal aspirates, pus swabs, cerebral spinal fluid (CSF), catheters, and high vaginal swabs (HVS). Identification was done by the five tube method on triple sugar iron agar, sulphur indole motility agar, Simmon's citrate agar, MRVP broth and urea agar. Gram stain test were also done to confirm morphological characteristics.

Antibiotic susceptibility to seven aminoglycosides; amikacin (30µg), gentamicin (10µg), kanamycin (30µg), neomycin (30µg), streptomycin (10µg), tobramycin (10µg) from Oxoid Limited United

Kingdom and High level Resistance (HLR) spectinomycin (300µg) Rosco Diagnostica, Denmark. The tests were carried out using the disc diffusion method on Mueller Hinton Agar and incubated at 37°C for 18-24 hours. Disk susceptibility tests were interpreted according to the guidelines provided by the manufacture's interpretation charts. *Escherichia coli* ATCC 25922 with known MICs was used as Standard control organism.

DNA Extraction was carried out whereby an 18-24hr single colony of each isolate was suspended in 1 ml of sterile distilled water, which was then heated at 95°C for 10 minutes. After heating, centrifugation was done at 14,000 rpm for 6 minutes at 4°C. The DNA-containing supernatant was extracted and used as the source of template for further PCR amplification experiments.

Selected isolates were tested for AMEs by using the PCR primers listed in Table 1. PCR amplification reactions was performed in a volume of 25 µl containing 12 µl of Qiagen PCR Master Mix (Qiagen GmbH, Hilden, Germany), 1.0 µM concentrations of each primer, 6µl of PCR water and 5 µl of DNA template. PCR products were analysed by gel electrophoresis at 100V for 1½ hours in a 2% agarose gel stained in Ethidium bromide. Bioline Hyperladder 1 was used as the standard marker.

Ethical clearance was obtained from Kenya Medical Research Institute (KEMRI) Scientific Committee and Ethical Review Committee and Aga Khan University Hospital (AKUH) Scientific and Ethical Review Committees.

3.0 Results

Aminoglycoside susceptibility testing of *E. coli, Klebsiella* spp. and *Acinetobacter baumannii* showed susceptibility to amikacin and HLR spectinomycin and relative resistance to the kanamycin, tobramycin, streptomycin, gentamicin and neomycin. The isolates collected from urine, blood, pus swabs and tracheal aspirates specimens showed resistance to streptomycin, kanamycin, gentamicin and tobramycin and susceptibility to amikacin and HLR spectinomycin. Overall, the isolates from Aga Khan University Hospital (AKUH- New) collected in 2007-2008 showed resistance to streptomycin (87%), kanamycin 81%), gentamicin (69%), tobramycin (65%), neomycin (62%), amikacin(46%) and spectinomycin(36%) respectively. The AKUH- old isolates collected in 2001- 2006 showed resistance to neomycin (36%), kanamycin (34%), gentamicin (32%), streptomycin (30%), tobramycin (26%), spectinomycin (11%), and amikacin (4%). The KNH- old isolates showed resistance to neomycin (47%), streptomycin (36%), kanamycin (34%), gentamicin (32%), tobramycin (26%), spectinomycin (17%), and amikacin (2%), respectively (Figure 1).

There was a remarkable increase in resistance of seven Aminglycoside antibiotics tested on the four Gram negative bacteria from Aga Khan University Hospital isolates collected over eight years (2001-2008). Kanamycin showed 68% increase in resistance, amikacin showed 40% increase, streptomycin 57%, gentamicin 37%, tobramycin 39%, neomycin 26% and HLR spectinomycin 24% (Table 2).

Aminoglycoside Modifying Enzymes (AMEs) were detected phenotypically as described by Livermore *et al.* (2001). It is possible to determine the presence of AMEs by testing the susceptibility of isolates against a range of clinically available aminoglycosides as a pattern of resistance emerges which is unique to a specific enzyme. Based on this phenotypic interpretation *P. aeruginosa* had the most AME genes seen to be conferring 81% resistance by impermeability (Table 3). A total of six aminoglycoside modifying enzymes (AMEs) were detected based on there resistance to selected Aminoglycosides determining the number of isolates per primer. The results show that majority of the MDR *P. aeruginosa* contain 83% of the aminoglycoside modifying enzymes genes tested while *A. baumannii* isolates contained the 16% AME genes. Some of the isolates were found to contain more than one AME gene and are of great interest (Table 4).

PCR products for *AAC(6')-1b-cr* and *AAC(3)-IIa* genes showed they amplified at 509bp and 300bp (Plate 1 and 2) respectively. *AAC(6')-1b-cr* confers resistance to Aminoglycosides; kanamycin, tobramycin and amikacin, and Quinoloes; nalidixic acid, ciprofloxacin and norfloxacin. *AAC(3)-IIa* confers resistance to gentamicin and tobramycin. Isolates with these resistance profiles were selected from both stored KEMRI isolates collected in 2001-2006 and AKUH- new collected in 2007-2008. *AAC(6')-1b-cr* gene had the largest number of micro-organisms test positive (60%).

4.0 Discussion and Conclusion

In Kenya, aminoglycosides most widely used clinically are gentamicin, streptomycin and kanamycin which showed the greatest percentages of resistance. AKUH- New isolates showed the highest percentages of resistance with 87%, 81% and 69% resistance to streptomycin, kanamycin and gentamicin, AKUH- old isolates showed 30%, 34% and 32% and resistance to streptomycin, kanamycin and gentamicin and finally KNH-old isolates showed 36%, 34% and 32% resistance to streptomycin, kanamycin and gentamicin. A study by Över *et al.,* (2001) tested 696 Gram-negative bacteria for resistance to aminoglycosides and they found resistance rates to be very high for Gentamicin (94.5%). In a similar study by Miró *et al.,* (2008) in Spain during a period of 3 months 803 *Enterobacteriaceae* isolates were tested against aminoglycosides and the isolates were most resistant to streptomycin 42.6%, followed by kanamycin 12.8% and gentamicin 8.4%. These high levels of resistance to streptomycin, gentamicin and kanamycin may be attributed to their prolonged and continuous use.

The present study confirms that there exists a link between the type of aminoglycoside used and the kind of aminoglycoside resistance mechanism that will prevail. Notable about the phenotypic characterisation was that MDR *P. aeruginosa* was seen to harbour numerous AME genes and confers 81% resistance by impermeability. In a study by Poole, (2005) the percentage incidence of *P. aeruginosa* most prevalent AMEs as follows Aac6')-II 18.39% and Ant(2")-I 11.87% while impermeability played the most part in conferring resistance with 26.15% incidence. The occurrence of numerous AME genes in MDR *P. aeruginosa* was of great interest this is because more than one mechanism of aminoglycosides resistance may be at play at the same given time. *P. aeruginosa* has a very active efflux system causing the reduction of intracellular concentration of aminoglycosides by the outer membrane changes in permeability and inner membrane decrease in transport leading to trapping the drug. The presence of AMEs in integrons and transposons may explain the multi-drug resistance of many aminoglycoside-resistant *P. aeruginosa* isolates (Poole, 2005).

The genotypic results of the six AMEs amplified by PCR showed the most widespread AME in the present study was *AAC(6')-Ib-cr* (45.9%), followed by *AAC(3)-II* (30.9%), *AAC(6')-II* (25.9%), *AAC(6')-I* (22.2%), and *AAC(3)-I* (16.3%). No Ant(4')-IIb enzyme was detected. A study on molecular characterisation of aminoglycosides resistance in Spain, (2008) on *Enterobacteriaceae*, *AAC-3-IIa* gene was 10% prevalent, *AAC-6'-Ib* was 3.8%, and *AAC-6'-Ic* was 0.3%. Twenty two percent of the strains presented more than one enzyme (Miró *et al.,* 2008). The enzyme Aac(6')-Ib-cr was the most widespread. In the micro-organisms tested in this study, the enzyme occurred at a frequency of 22% in *Klebsiella* spp., 19% in *P. aeruginosa*, 14% in *E. coli* and 5% in *A. baumannii*. The discovery of the *cr* variant of the aminoglycoside-(6)-N-acetyltransferase (*AAC[6']-Ib-cr*) gene confers resistance against two unrelated classes of antibiotics-aminoglycoside and quinolone- by changing two amino acids Trp102Arg and Asp179- Tyr. The clinical appearance of *AAC(6')-Ib-cr*, including its molecular and phenotypic characteristics, and its association with other antibiotic resistance genes have not been clarified to date (So Youn Shin *et al.,* 2009) . Moreover, there has been no recent study on the prevalence of *AAC(6')-Ib-cr* in isolates from Kenya. The *AAC(6')-Ib-cr* gene has been found in a gene cassette located inside class 1 integron (Fihman *et al.,* 2008). This shows that the gene is capable of rapid horizontal transfer between *Enterobacteriaceae* isolates.

Aac(6')-I enzyme is also quite important as it has gained attention for conferring resistance to naturally occurring Kanamycins and Tobramycin as well as to their semi-synthetic derivatives Amikacin and Neitlmicin. A positive correlation between increased Amikacin use and the occurrence of enzyme-mediated resistance has been described. Amikacin a semi-synthetic aminoglycoside has an acylated N-1 group which makes it a poor substrate for a number of modifying enzymes (Schmitz *et al.,* 1999). The low incidence of Aac (6')-I in Italian and German hospitals reflects the low percentage of Amikacin usage (15.8% and less than 10% of the total aminoglycosides usage, respectively) (Neonakis *et al.,* 2003). Here in Kenya, hospitals are extensively using Amikacin in treatment of severe nosocomial infections thus increasing the level of resistance by 40% over the years as reported in this study. This may be attributed to the presence of this enzyme which is not only highly transferable as it is located within integrons and transposons but has been seen to co-exists very frequently with other antibiotic-inactivating enzymes such as ESBLs (Neonakis *et al.,* 2003).

The future of unravelling more mechanisms of Aminoglycoside resistance lies in the determination of the 3D atomic structure of AMEs by X-crystallography. Four AMEs crystal structures have been reported namely; Aac(3), Aac(6'), Ant(4') and Aph(3')-IIIa (Neonakis *et al.,* 2003). This information has been useful in the application of structural modifications of aminoglycosides resulting in reduction of the modified antibiotic to bind to the target RNA due to unfavourable steric and/or electrostatic interactions. Attempts to make semi-synthetic aminoglycosides that circumvent resistance enzymes have been done although these await further experimentation. Examples of these are Dibekacin which lacks the 3'-hydroxyl group and therefore does not substrate for Aph(3') compounds. Amikacin and Isepamycin have an acylated N-1 group which makes them poor substrates for several AMEs (Kotra *et al.,* 2000).

5.0 Conclusion

This study showed that the older naturally derived aminoglycoside antibiotics like streptomycin, kanamycin, and gentamicin showed very high levels of resistance in the clinical isolates of genera *Escherichia*, *Klebsiella, Pseudomonas* and *Acinetobacter*. MDR *Pseudomonas aeruginosa* was detected in the study and showed resistance to Carbapenems. The occurrence of numerous AME genes in MDR *P. aeruginosa* was of great interest indicating possibility of more than one mechanism of aminoglycosides resistance to be at play at the same given time. Presence of AMEs was established both phenotypically and genotypically. The genes detected were *AAC(6')-Ib-cr* (45.9%), followed by *AAC(3)-II* (30.9%), *AAC(6')-II* (25.9%), *AAC(6')-I* (22.2%), and *AAC(3)-I* (16.3%).

6.0 Acknowledgement

We thank the Mobile Genetic Elements (MGE) project at the Centre for Microbiology Research of Kenya Medical Research Institute (KEMRI) for funding this project, KEMRI for providing laboratory space, Aga Khan University Hospital and Kenyatta National Hosptical for providing bacterial isolates.

References

Al Naiemi, N., Heddema, E. R, Bart A., De Jonge, E, Vandebrouke-Grauls ,C. M., Savelkoul, P. H. and Dium, B. (2006). Emergence of multi-drug resistant Gram negative bacteria during selective decontamination of the digestive tract on an Intensive care unit. *Journal of Antimicrobial Chemotherapy*, **58**(4), pp 853-6.

Davies, J. and Wright, G. D. (1997). Bacterial resistance to aminoglycosides antibiotics*. Trends Microbiology,* **5**, pp 234-240.

Doi, Y., Wachino, J., Yamane, K., Shibata, N., Yagi, T., Shibayama, K., Kato, H. and Arakawa, Y. (2004). Spread of novel Aminoglycoside Resistance gene aac(6')-Iad among Acinetobacter Clinical isolates in Japan. *Antimicrobial agents and Chemotherapy*, **48** (6) pp 2075-2080.

El Kholy Amani, H. Baseem, G. S. Hall, G. W. Procop and D. L. Longworth (2003). Antimicrobial resistance in Cairo, Egypt 1999-2000: a survey of five hospitals*. Journal of Antimicrobial Chemotherapy,* **51**, pp 625-630.

Francetić, I., Kalenić, S., Huić, M., Merčep, I., Makar-Aušperger, K., Likić ,R., Erdeljić, V., Tripković, V., and Šimic, P. (2008). Impact of Aminoglycoside Cycling in Six Tertiary Intensive Care Units: Prospective Longitudinal Interventional Study*. Croatia Medical Journal*. **49**(2), pp 207-214.

Fihman, V., Lartigue, M. F., Jacquier, H., Meunier, F., Schnepf, N., Raskine, L., Riahi, J., Sanson-le Pors, M. J. and Berçot, B. (2008). *Appearance of aac(6')-Ib-cr gene among extended spectrum beta-lactamase-producing* Enterobacteriaceae *in a French hospital. Journal of Infection,* **56**, pp 454-459.

Hart, C. A. and Kariuki, S. (1998) Antimicrobial resistance in developing countries*. BMJ 317*, pp 647-51.

Kotra, L. P., Hadda, J. and Mobashery, S. (2000). Aminoglycoside: perspectives on mechanisms of action and resistance and strategies to counter resistance*. Antimicrobial Agents and Chemotherapy,* **44**, pp 3249–3256.

Lawley, T., Wilkins, B. M. and Frost, L. S.(2004), pp. 203-226, In Funnell, B. E. and Phillips, G. J. (**Eds**.), Plasmid Biology, ASM Press, Washington, DC.

Livermore D. M. (1984). Penicillin-binding proteins, porins and outer-membrane permeability of carbenicillin-resistant and -susceptible strains of Pseudomonas aeruginosa. *Journal of medical Microbiology* **18**(2), pp 261-70.

Livermore, D. M. (2001) *Of* Pseudomonas*,* porins, pumps and carbapenems*. Journal of Antimicrobial Chemotherapy,* **47**(3), pp 247-50.

Livermore, D. M, Winstanley T.G, Shannon K. P (2001). Interpretative reading: recognising the unusual and interfering resistance mechanisms from resistance phenotypes*. Journal of Antimicrobial Chemotherapy,* **48**(Suppl S1), 97.

Mingeot-Leclercq, M. P., Glupczynski Y., and Tulkens, P. M. (1999). Aminoglycosides: Activity and Resistance. *Antimicrobial Agents and Chemotherapy,* 43, pp 727-37.

Miró, E., Grunbaum, F., Gómez, L., Mirelis, B., and Navarro, F. (2008). Molecular characterization of aminoglycoside resistance in Enterobacteriaceae.

Mshana, S. E., Kamugisha, E., Mirambo, M., Chakraborty, T. and Lyamuya, E. F. (2009). Prevalence of multiresistant Gram-negative organisms in a tertiary hospital in Mwanza, Tanzania. BMC Research notes 2:49.

Musoke, R. N. and Revathi, G. (2000). Emergence of Multidrug-resistant Gram-negative organisms in a neonatal unit and the therapeutic implications*. J. Trop. Pediatr*., **46**, pp 86-91.

National Committee for Clinical Laboratory Standards (2005), Performance standards for antimicrobial susceptibility testing; twelfth informational supplement. Approved standard M100-S12, NCCLS, Wayne, PA.

Neonakis, I., Gikas, A., Scoulica, E., Manios, A., Georgiladakis, A. and Tselentis, Y. (2003). Evolution of aminoglycoside resistance phenotypes of four Gram-negative bacteria: an 8 year study survey in a university hospital in Greece. *International Journal of Antimicrobial agents,***22**, pp 526-531.

Neo-sensitabs- Susceptibility testing 19th Edition User's Guide. 2007/2008. Rosco diagnostica. Denmark.

Okeke, I. N., Fayinka, S. T and Lamikanra, A. (2000). Antibiotic resistance trends in Escherichia coli from apparently healthy Nigerian students *(1986-1998). Emerg Infect Dis.*, **6**, pp 393-396.

Över, U., Gur, D., Unal, S., Miller, G. H. and The Aminoglycoside resistance study group (2001). The changing nature of aminoglycoside resistance mechanisms and prevalence of newly recognized resistance mechanisms in Turkey. *European Society of Clinical Microbiology and Infectious Diseases.* **7**, pp 470-478.

Poole, K. (2005). Aminoglycoside Resistance Pseudomonas aeruginosa. *In Antimicrobial Agents and Chemotherapy*. **49**(2), pp 479-487.

Schmitz, F. J., Verhoef, J. and Fliut, A. C. (1999). Prevalence of aminoglycosides resistance in 20 European university hospitals participating in the European SENTRY Antimicrobial Surveillance ProGramme. *European Journal of Clinical microbiology Infectious diseases,* **18**, pp 414-421.

Slama, T. (2008). Gram-negative antibiotic resistance; there is a price to pay. The critical care forum: 12(suppl 4):S4.

Shakil, S., Khan, R., Zarrilli, R., and Khan, U. (2008. Aminoglycoside versus bacteria –a description of the action, resistance mechanism, and nosocomial battleground*. Journal of Biomedical Science*, **15,** pp 5-14.

Shaw, K. J., Rather, P. N., Hare, R. S. and Miller, G. H. (1993). Molecular Genetics of Aminoglycoside Resistance Genes and Familial Relationships of the Aminoglycoside-Modifying Enzymes. *Microbiological Reviews,* **57**, pp138-63.

So Youn Shin, Kye Chul Kwon, Jong Woo Park, Jeong Hoon Song, Young Hyun Ko, Ji Youn Sung, Hae Won Shin, and Sun Hoe Koo (2009). Characteristics of aac(6')-Ib-cr Gene in Extended-Spectrum β-Lactamase-Producing Escherichia coli *and* Klebsiella pneumoniae Isolated from Chungnam Area*. Korean J Lab Med,* **29**, pp 541-50.

Vakulenko, S. B. and Mobashery, S. (2003*).* Versatility of Aminoglycosides and prospects for their future. *Clinical Microbiology Reviews*. **16**(3), pp 430-450.

Wright, G. D. (1999). Aminoglycoside- modifying enzymes. Elsevier Science ltd. **2**, pp 499-503.

Table 1: Selected Aminoglycoside resistance genes and Integrons sequences detected by PCR

AME genes (Aminoglycoside Resisted)	F/ R Primer	PCR cycle
aac(6')-I (Tob, Amk, Kan)	TATGAGTGGCTAAATCGAT/ CCCGCTTTCTCGTAGCA	94°C 15min, (94°C 45s, 55°C 45s, 72°C 45s) 34 cycles, 72°C 10min
aac(6')-II (Tob, Amk, Kan)	CGCTTGTTGATTTGCTGCT GTTCGC/TTGAAACGACCT TGACCTTCCG	94°C 15min, (94°C 45s, 55°C 30s, 72°C 1min) 30 cycles,72°C 10min
aac(6')-1b-cr (Tob, Amk, Kan+ NA, Cip, Nor)	TTGCGATGCTCTATGAGTG GCTA/ CTCGAATGCCTGG CGTGTTT	94°C 5min, (94°C 45s, 55°C 45s, 72°C 1min) 36 cycles, 72°C 10min
aac(3)-I (Gen, Tob)	AGCCCGCATGGATTTGA/ GGCATACGGGAAGAAGT	94°C 15min, (94°C 1min, 55°C 1min, 72°C 1min) 30 cycles, 72^{0}C 10min
aac(3)-IIa (Gen, Tob)	GCTAAACTCCGTTACC/ TAGCACTGAGCAAAGCC	94°C 15min, (94°C 45s, 60°C 30s 72°C 90s) 30 cycles, 72°C 10min
ant(4')-IIb (Tob, Kan)	GAGAACCCATATGCAACA TACTATCGCC/ TAGAATTCT AGCGCGCAC TTCGCTCTTC	94°C 15min, (94°C 1min, 58°C 30s, 72°C 1min) 35 cycles, 72°C 10min

Tob- Tobramycin, Kan- Kanamycin, Gen- Gentamicin, Amk- Amikacin, NA- Nalidixic acid, Cip- Ciprofloxacin, Nor- Norfloxacin

Table 2: Aminoglycoside resitance of Aga Khan University Hospital isolates collected 2001-2008

Isolate Source	Year of Collection	Percentage prevalence of resistance (%) AK	K	CN	S	TOB	NEO	SPCT
AKUH -new	2007-2008	46	81	69	87	65	62	35
AKUH- old	2001-2006	4	34	32	30	26	36	11
% Increase		**40**	**68**	**37**	**57**	**39**	**26**	**24**

AK-Amikacin, K-Kanamycin, CN-Gentamicin, S-Streptomycin, TOB-Tobramycin, NEO-Neomycin and SPCT- Spectinomycin.

Table 3: Phenotypic Characterisation of Aminoglycoside resistance profiles of E. coli, Klebsiella spp. and Pseudomonas aeruginosa

Test M.O	GEN	TOB	AMK	KAN	NEO	Gene present	Frequency
E. coli	S	S	S	S	S	Classical*	-
	R	S	S	S	S	*AAC(3)-I*	5%
	R	R	S	R	S	*AAC(3)-II*	5%
	R	R	S	r	R	*AAC(3)-IV*	44%
	S/r	R	R	R	R	*AAC(6')*	2%
	R	R	S	R	R	*ANT(2')*	5%
	S	S	R	R	S	*APH (3')*	-
Klebsiella spp.	S	S	S	S	S	Classical	-
	R	S	S	S	S	*AAC(3)-I*	3%
	R	R	S	r	S	*AAC(3)-II*	3%
	S/r	R	R	R	R	*AAC(6')*	6%
	R	S	S	R	S	*ANT(2')*	-
	S	S	S	R	R	*APH(3')*	37%
P. aeruginosa	S	S	S	S	S	Classical	-
	R	S	S	R	R	*AAC(3)-I*	-
	R	R	S	R	R	*AAC(3)-III*	81%
	S/r	R	R	R	R	*AAC(6')*	86%
	R	R	S	R	R	*AAC(6')-II*	81%
R	R	S	R	R		*ANT(2')*	81%
	S	S	S	R	R	*APH(3')*	10%
	R	R	R	R	R	Impermeability	81%

*Classical= Historic phenotype of the species, without acquired resistance
S= Susceptible, R= Resistant, r= reduced zones but likely to remain susceptible at standard breakpoints (Livermore *et. al.,* 2001)
AK-Amikacin, KAN-Kanamycin, GEN-Gentamicin, TOB-Tobramycin and NEO-Neomycin.

Table 4: Presence of Six Aminoglycoside Modifying Enzymes in E. coli, Klebsiella spp., Acinetobacter baumannii and Pseudomonas aeruginosa isolates

AME genes	Amg resistance Conferred	No. tested	Positive M.O for AME genes				PCR product
			E.coli	*Kleb.*spp	*Pseudo*	*A. bau*	
AAC(6')-I	Tob, Amk, Kan	**27**	-	2	5	-	**1,100bp**
AAC(6')-II	Tob, Gen, Kan	**27**	1	-	5	-	**1,507bp**
AAC(6')-1b-cr	Tob, Gen, Kan+ NA, Cip, Nor	**37**	5	8	7	2	**509bp**
AAC(3)-I	Gen, Tob	**55**	2	2	5	-	**227bp**
AAC(3)-IIa	Gen, Tob	**55**	6	5	6	-	**300bp**
ANT(4')-IIb	Tob, Kan	**27**	-	-	-	-	-

KAN-Kanamycin, AMK- Amikacin, GEN-Gentamicin, TOB-Tobramycin, NA- Nalidixic Acid, CIP-

Ciprofloxacin and NOR-Norfloxacin.

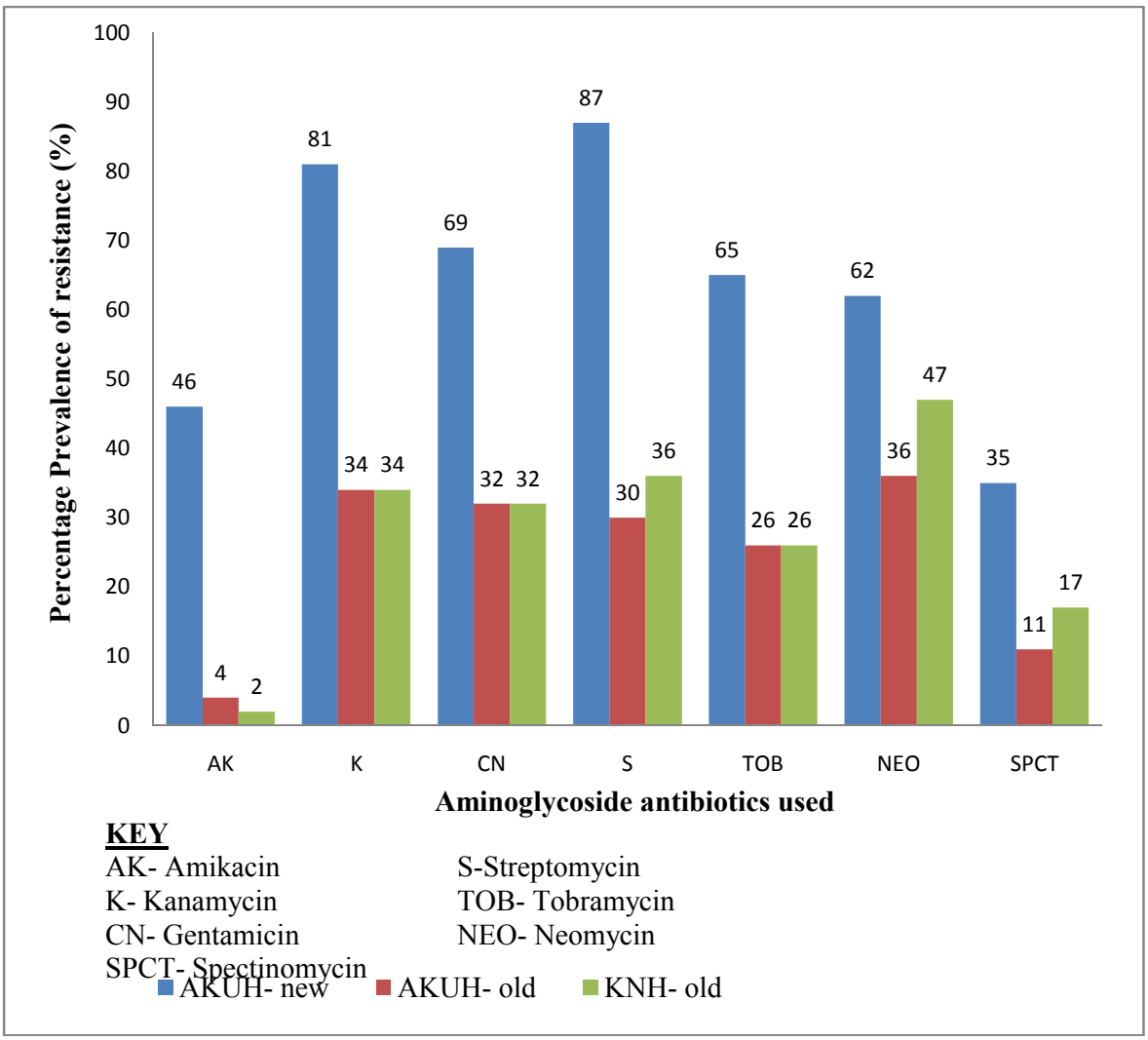


Figure 1: Antibiotic resistance of isolates from Stored KNH-old and AKUH-old laboratory (2001-2006) and AKUH- new (2007-2008) to seven Aminoglycoside antibiotics

Plate 1: Gel photograph of *Aac(6)-Ib-cr* gene PCR products. The resistance gene amplified at 509kb. **Lanes: M**- DNA Marker- Bioline Hyperladder I, 1. ***E.coli*** 23, 2. *E.coli* 55, 3. *E.coli* 61, 4. *E.coli* 5875, 5. *E.coli* 6303, 6. ***E.coli*** **6701, 7.** *Klebsiella* spp. 2, 8. *Klebsiella* spp. 8, 9. *Klebsiella* spp. 34, 10. ***Klebsiella*** **spp.** 6681 11. *Klebsiella* spp 6308,12. *P.aeruginosa* 43, 13. *P. aeruginosa* **63, 14.** ***P.*** *aeruginosa* 81,15. *P. aeruginosa* 6682,16. *P.aeruginosa* 5876 and 17. ***A. baumannii*** 5801.

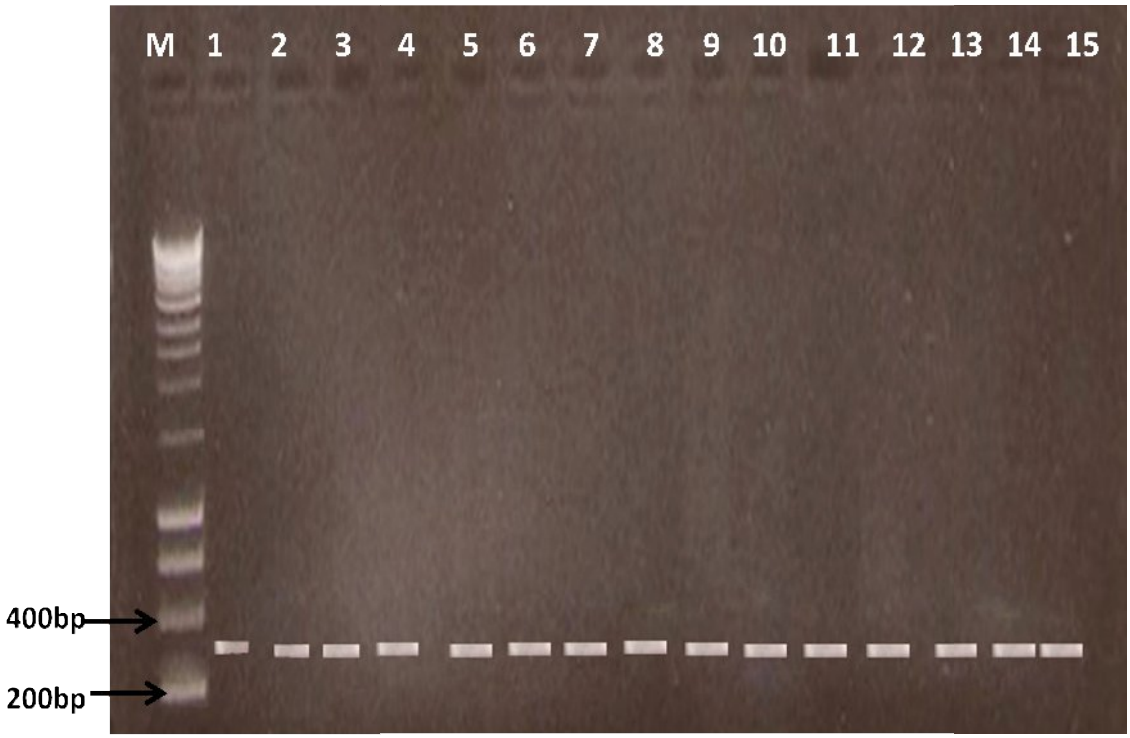


Plate 2: *Aac(3)-IIa* PCR products. The *aac(3)-IIa* gene was amplified at approximately 300bp. **Lanes: M-** DNA Size Marker- Hyper ladder I, 1. ***E.coli*** 18, 2. *E.coli* 21, 3. *E.coli* 6680, 4. *E.coli* 6698, 5. *E.coli* 6699, **6. *Klebsiella*** spp.8, 7. *Klebsiella* spp.9, 8. *Klebsiella* spp. 1667, 9. *Klebsiella* **spp. 1671, 10.** *Klebsiella* spp. 5422, 11. *P. aeruginosa* 43, 12. *P. aeruginosa* **51, 13. *P.*** *aeruginosa* 64, 14. *P. aeruginosa* 65 and 15. *P. aeruginosa* 5876

ON THE AGROFORESTRY SYSTEM AND *IN SITU* CONSERVATION OF MEDICINAL PLANT GERMPLASM IN TRANS-NZOIA DISTRICT, KENYA

J. M. Ochora [1], J. M. Onguso[2] and J. I. Kany [3]
[1,3]Department of Botany, Jomo Kenyatta University of Agriculture and Technology, Nairobi
[2] Institute of Biotechnology Research, Jomo Kenyatta University of Agriculture and Technology, Nairobi
E-mail: jmemba@yahoo.com

Abstract
In sub-Saharan Africa about 80% of the ever increasing population depends on ethnomedicine for their healthcare since modern medicine is mostly expensive or unavailable in rural homesteads. However, ethnomedicine is the one presently recognised as the most effective in treating new emerging diseases such as HIV/AIDS since no effective conventional medicine exists for their cure. Medicinal plants germplasm, which are the major sources of ethnomedicine form an important part of forests and riverine vegetation in Kenya. These important plants include *Warburgia, Rhas* spp., *Aspilia, Acacia, prunus, Molinga*, *Brascae*, *Aloe*, and *Terminalia*. These plants are not only useful to man as a source of medicine but are microhabitats for many animals as well as forming "refugia" to many insects species. In Kenya, due to land degradation and rampant deforestation in agriculturally high potential areas, medicinal plants genetic resource is threatened. The most medicinally popular of these plant species, which are mostly biome restricted, are facing extermination. This paper reports conservation concerns in agriculturally high potential Trans-Nzoia District in Kenya. The study based on field surveys revealed that of the ca. 806 plants species in 92 families about 36 species are used for medicinal purposes. The plants are threatened in their indigenous localities in the District. The study recommends participatory *in situ* plant conservation in the District along maize and wheat farm hedges.

Key words: Agroforestry, *in situ* conservation, medicinal plants, indigenous medicines

1.0 Introduction

As the demand for arable land and urban settlement increases in Kenya, more of the existing forest land is being excised for use as farmlands and urban infrastructural expansion. These activities have led to clearing of important forests and game reserves. The forest depletion seems to relate very well with population pressure backed by the fact that the backbone of Kenya's economy is agriculture.

Although surveys to map the proportion of plant species that are lost each year have not been comprehensively carried out, it is not surprising to discover that an overwhelming number of plants especially those of medicinal importance is eroded.

As previously established, Kenya has a rich plant heritage with the most potent biochemicals (Kokwaro, 1983; Riley and Brokensha, 1988). Even if only a few medicinal plants have been documented for deforested areas of Kenya (Kanya 2004; Ochora *et al*., 2005) it is envisaged that many more destroyed plants fall under this category. *Ex situ* conservation strategies especially in garden environment (Frankel et al., 1995) are not suitable for trees and also for large populations of herbs, scrubs or shrub species.

2.0 Methods

2.1 Establishment of the Baseline and Number of Sampling (Transect Lines)

The transect intercept method *(Grieg-Smith, 1983)*of sampling was employed. At each sampling site, a 1 km baseline with a west-east orientation was established. These points were randomly placed along this baseline through which a sampling line (transect) passed. Three transect lines (each 50 m) were established which intersected the baseline at midpoints (William, 1986). The orientation for each transect was randomized by selecting a number between 0^{o} and 360^{o}.

2.2 Measurement on Each Baseline

As each line was traversed, the plants species intercepted by the transect line were identified to produce a species list (Agnew, 1994; Beetle, 1994). Where field identification of species was not possible in the field, voucher specimens were collected for later identification at the East African Herbarium (EA).

The field work was done for a period of one year during cropping and non-cropping seasons. In each sampling site in the farms a baseline, 1 Km. long, was established orientating in a west-east direction. Three random points were located along the baseline through which sampling line (transect) passed.

Transect lines were used such that as the line was traversed the plant species intercepted by the transect line were identified to produce a species checklist. The recorded plants were compared with the vegetation lists for Mt. Elgon forest available at the East African Herbarium. This montane vegetation is the remnant of indigenous plants of the District.

3.0 Results

A checklist of plants ca. 806 in 92 families was established (Table 1). Except for plants in the categories of herbs and scrubs that easily rejuvenate from propagules in the farmlands, most shrubs and trees earlier recorded for Trans-Nzoia District are of rare occurrence. Conspicuously absent were the highly medicinal plants such as *Warburgia*, *Prunus*, *Carissa*, and *Rhas* (Table 2) that were once dominant in the region.

Table 1: A checklist of plant species recorded in Trans-Nzoia District during cropping and non-cropping seasons

Family	Plant Species	Family	Plant Species
Acanthaceae	*Acanthus pubescens*	**Amaranthaceae**	*Achylanthes aspera*
	Asystasia mysorensis		*Amaranthus caudatus*
	Asystasia schimperi		*Amaranthus graecizana*
	Barleria micrantha		*Amaranthus hybridus*
	Dyschoriste radicans		*Celosia trigyna*
	Hygrophila auriculata		*Cyathula polycephala*
	Hypoestes forskahlii		
	Justicia exigua	**Amaryllidaceae**	*Scadoxus multiflorus*
	Justicia flava		
	Justicia striata	**Anacanthaceae**	*Rhus natalensis*
	Justicia whytei		*Rhus vulgaria*
	Monechma debile		
	Ruellia patula	**Anacardiaceae**	*Lannea edulis*
	Thunbergia elliotii		*Mangifera indica*
	Thunbergia gregorii *Tithonia aethiopica*		*Ozoroa insignis*
	Agave sisalan	**Annonaceae**	*Annona squamosa*
Anthericaceae	*Chlorophytum gallabatense*	**Apiceae**	*Sanicula elata*
Apocynaceae	*Carissa edulis*	**Araceae**	*Arisaema enneaphyllum*
	Landolphia buchananii		
Araliaceae	*Cussonia holstii*	**Aslepiadiaceae**	*Periploca linearifolia*
			Striga hermonthica
Asphodelaceae	*Bulbinella abyssinica*	**Asteraceae**	*Acanthospermum autriale*
Bignoniaceae	*Jacaranda mimosifolia*		*Acanthospermum glabratum*
	Markhamia lutea		*Acanthospermum hispidium*
	Spathodea campanulata		*Acmella calirhiza*
			Ageratina adenophora
Boraginaceae	*Cordia Africana*		*Ageratum conyzoides*
	Cynoglosum coeruleum		*Ageratum houstoniamum*
	Cynoglossum geometricum		*Anthemis tigreensis*
	Cynoglosum lanceolatum		*Artemisia afra*
	Ehretia cymosa		*Aspilia pluriseta*
	Trifolium burchellianum		*Bidens pilosa*
			Blumea aurita
Brassicaceae	*Crambe kilimandscharica*		*Balumea scaposa*
	Raphanus sativus		*Bothriocline tomentosa*
Bromeliaceae	*Ananas comosus*		*Centaurea mollis*
			Cirsium buchwaldii
Buddlejaceae	*Buddleja madagascariensis*		*Conyza aegyptiaca*
	Buddleja polystachya		*Conyza schimperi*
			Conyza stricta
Burseraceae	*Commiphora Africana*		*Conyza sumatrensis*
			Conyza volkensii

Caesalpiniaceae	*Chamaecrista hildebranditii*		*Crassocephalum afromontana*
	Chamaecrista mimosoides		*Crassocephalum mannii*
	Piliostigma thonningii		*Crassocephalum montuosum*
	Senna didymobotrya		*Crassocephalum picridifolium*
	Senna singueana		*Crassocephalum vitellium*
	Canjanus cajan		*Crepis carbonaria*
			Dichrocephala integrifolia
Capparaceae	*Cleome monophylla*		*Emilia discrifolia*
	Gynandropsis gynandra		*Euryops brownie*
			Galinsoga alba
Caricacea	*Carica papaya*		*Galinsoga parviflora*
			Gamolepis chrysanthemoifes
Caryophyllaceae	*Cerastium indicum*		*Gerbera viridifolia*
	Cerastium octandrum		*Gnaphalium luteo-album*
	Drymaria cordata		*Gnaphalium rubriflorum*
	Silene burchellii		*Guizotia scabra*
	Silene gallica		*Gutenbergia bonariensis*
	Basella alba		*Gutenbergia cordofolia*
			Helianthus annua
Casuarinaceae	*Cassuarina cannighamii*		*Helichrysum cymosum*
			Helichrysum cymosum
Calastraceae	*Maytenus heterophyla*		*Helichrysum formosissimum*
	Maytenus senegalensis		*Helichrysum gerberifolium*
			Helichrysum odoratissimum
Chenopodiaceae	*Chenopodium opulifolium*		*Helchrysum setosa*
	Chenopodium procerum		*Inula decipiens*
			Lactuca capensis
Compretaceae	*Compretum collinum*		*Lagascea alata*
	Compretum molle		*Lagascea mollis*
			Laggera brevipes
Commelinaceae	*Anailema johnsonii*		*Launaea cornuta*
	Commelina Africana		*Melanthera scandens*
	Commelina benghalensis		*Microglossa pyrifolia*
	Commelina repens		*Pycreus lanceolatus*
			Schkuhria pinnata
Convolvulaceae	*Convolvulus kilimandschari*		*Sigesbeckia abyssinica*
	Convolvulus mombasana		*Solanecio angulatus*
	Dichondra repenes		*Sonchus asper*
	Evolvulus alsinoides		*Sonchus oleraceus*
	Falkia canescens		*Sporobolus Africana*
	Ipomoea batatas		*Teclea nobilis*
	Ipomoea kituiensis		*Tithonia diversifolia*
	Ipomoea obscura		*Toddalia asiatica*
	Ipomoea purpurea		*Vernonia auriculifera*
			Vernonia brachytrichoides
Crassulaceae	*Bryophylum pinnatum*		*Vernonia galamensis*
	Kalanchoe densiflora		*Vernonia hymenolepis*
	Kalanchoe lanceolata		*Vernonia karaguensis*
	Kalanchoe mitejea		*Vernonia lasiopus*
			Vicia faba

Cruciferae	*Brassica integrifolia*	**Cupressaceae**	*Cupressus lustanica*
	Brassica juncea		
	Brassica nupus	**Cyperaceae**	*Bothrichloa inscupta*
	Brassica oleraceae		*Carex monostachya*
	Erucastrum arabicum		*Cyperus alba*
	Lepidium bonariense		*Cyperus assimilis*
			Cyperus bulbosa
Cucurbitaceae	*Coccinia grandis*		*Cyperus dichrostachyus*
	Cucumis aculeatus		*Cyperus distans*
	Cucurbita pepo		*Cyperusgiolii*
	Lagenaria abyssinica		*Cyperus hemisphaericus*
	Lagenaria sphaerica		*Cyperus immensis*
	Mormodica calantha		*Cyperus involucratus*
	Mormodica foetida		*Cyperus kilimandschari*
	Mormodica friesiorum		*Cyperus latifolius*
	Mukia maderaspantana		*Cyperus macrocephala*
	Peponium pepo		*Cyperus niveus*
	Peponium volgellii		*Cyperus obusiflorust*
	Zornia glochidiata		*Cyperus rigidifolius*
			Cyperus rohlfsii
Dennstaedtiacaea	*Hypolepis goetzei*		*Cyperus rotudus*
	Pteridium aquilinum		*Cyperus sieberiana*
			Cyperus tenuifolia
Dioscoreaceae	*Dioscorae schimperiana*		*Cyperus tomaiophyllus*
	Diospyros abyssinica		*Fimbristylis subaphylla*
	Euclea divonorum		*Fuirena leptostachya*
			Mariscus macrocarpa
Epacridaceae	*Richea albeltii*		*Schoenoplectus corymbosus*
			Schoenoplectus senegalensis
Euphobiaceae	*Acaclypha volkensii*		*Scleria racemosa*
	Clutia abyssinica		
	Clusia robusta	**Flacourtiaceae**	*Dovyalis caffra*
	Manhot esculenta		*Dovyalis macrocalyx*
	Phyllanthus fischeri		*Oncoba spinosa*
	Ricinus communis		*Triticum aestivum*
	Tribulus terrestris		
	Acalypha volkensii	**Gentianaceae**	*Syzygium cordatum*
	Croton macrostachyus		
	Croton megalocarpus	**Geraniaceae**	*Geranium arabicum*
	Erythrococca bongensis		*Pelargonium quinquelobatum*
	Euphorbia crotonoides		
	Euphorbia hirta	**Guttiferae**	*Hypericum peplidifolium*
	Euphorbia inaequilatera		
	Euphorbia prostrate	**Iridaceae**	*Gladiolus psittacinus*
	Euphorbia ugandensis		*Gladiolus ukambanensis*
	Phyllantus spp.		
	Flueggea virosa	**Labiatae**	*Achyrospermum schimperi*
	Sapium ellipticum		*Ajuga remota*
			Fuerstia Africana

Lauraceae	*Persea Americana*		*Hoslundica opposite*
			Lantana camara
Liliaceae	*Gloriosa surperba*		*Leonotis mollissima*
	Ornithogalum tenuifolium		*Leonotis nepetifolia*
	Aloe lateritia		*Leucas calostachys*
	Asparagus africanus		*Leucas deflexa*
			Leucas glandis
Loranthaceae	*Phragamanthera usuiensis*		*Leucas martinicensis*
			Leucas mollis
Malvaceae	*Abutilon longicuspe*		*Leucas neuflizeana*
	Abutilon mauritianum		*Ocimum gratissimum*
	Hibiscus calyphyllus		*Ocimum kenyense*
	Hibiscus cannabinus		*Ocimum kilimandscharicum*
	Hibiscus diversifolius		*Ocimum lamiifolium*
	Hibiscus fuscus		*Plectranthus barbatus*
	Hibiscus greenwayi		*Plectranthus edulis*
	Hibiscus rhomboidea		*Plectranthus laxiflorus*
	Hibiscus trionum		
	Hibiscus vitifolius		*Plectranthus parvus*
	Kosteletzkya adoensis		*Pycnostachys stuhlmannii*
	Malva verticillata		*Salvia merjamie*
	Pavonia patens		*Salvia microphylla*
	Pavonia urens		*Satureia biflora*
	Sida acuta		*Stephanie abyssinica*
	Sida Africana		
	Sida cordifolia	**Melastomataceae**	*Dissotis brazzae*
	Sida rhombifolia		
	Sida tenuicarpa	**Melastomaceae**	*Dissotis brazzae*
	Sida ternata		
Meliaceae	*Ekebergia capensis*	**Meliaceae**	*Ekebergia capensis*
Melianthaceae	*Bersama abyssinica*	**Menispermaceae**	*Cissampelos mucronata*
Mimosaceae	*Acacia albida*	**Musaceae**	*Enzete ventricosa*
	Acacia gerrardii		*Musa parasidiaca*
	Acacia hockii		*Musa sapiens*
	Acacia lahai		
	Acacia meansii	**Myrsinaceae**	*Embelia schimperi*
	Acacia nilotica		*Maesa lanceolata*
	Acacia sieberina		
	Calliandra caly	**Myrtaceae**	*Eucalyptus camaldulensis*
	Entada abyssinica		*Eucalyptus saligna*
	Albizia gumifera		*Psiadia guajava*
			Syzygium guineensis
			Tegetes minuta
Nyctaginaceae	*Bougaivillea spectabilis*	**Oleaceae**	*Fraxinus pennsylvanica*
			Jasminum fluminense
			Olea capensis
			Schrebera alata

Onagraceae	*Jussiaea abyssinica*		
	Ludwigia abyssinica	**Oxalidaceae**	*Oxalis corniculata Oxalis latifolia*
			Oxalis obliquifolia
Palmae	*Phoenix reclinata*		
		Passifloraceae	*Passiflora edulis*
Papilionaceae	*Alysicarpus glumaceus*		
	Antopetitiana abyssinica	**Pedaliaceae**	*Sesamum angolensis*
	Astragalus atropilosulus		*Sesamum calycimum*
	Caesalpinia decapetala		
	Cassia mimosoides	**Phytolaceae**	*Phytolacca dodecandra*
	Cassia obtusifolia		
	Crotalaria brevidens	**Plantaginaceae**	*Plantago lanceolata*
	Crotalaria hyssopifolia		*Plantago palmate*
	Crotalaria incana		
	Crotalaria incanum		
	Crotalaria recta	**Poaceae**	*Sorgum vulgare*
	Crotalaria spinosa		*Andropogon abyssinicus*
	Desmodium adscendens		*Aristida adoensis*
	Desmodium intortum		*Beckeropsis uniseta*
	Desmodium repandum		*Bothriochloa inscupta*
	Desmodium uncintortum		*Bothriocline longipes*
	Dichrostachys cinerea		*Brachiaria brizantha*
	Eriosema macrostipulum		*Brachiaria decumbens*
	Eriosema pauciflorum		*Chloris gayana*
	Erythrina abyssinica		*Chloris pycnothrix*
	Glycine whytei		*Cymbopogon caesius*
	Indigofera arrecta		*Cymbopogon diplandra*
	Indigofera fischeri		*Cymbopogon dissolute*
	Indigofera mimosoides		*Cymbopogon nardus*
	Indigofera nairobiensis		*Cynodon dactylon*
	Indigofera spicata		*Dactyloctenium aegyptium*
	Indigofera volkensii		*Digitaria scalarum*
	Leucaena glauca		*Digitaria ternate*
	Phaseolus vulgaris		*Digitaria velutina*
	Pisum sativum		*Echinochloa pyramidalis*
	Pseudarthria hookeri		*Echinochloa haploclada*
	Pterolobium stellatum		*Eleusine coracana*
	Rhynchosia elegans		*Eleusine glaucum*
	Rhynchosia kilimandscharica		*Eleusine indica*
	Rhynchosia minima		*Eleusine jaegeri*
	Rhynchosia parkeri		*Eragrostis aspera*
	Sesbania sesban		*Eragrostis brownie*
	Tephrosia holstii		*Eragrostis ciliaris*
	Thalictrum rhyncocarpum		*Eragrostis exasperate*
	Trifolium usambarensis		*Eragrostis humidicola*
	Trimeria grandifolia		*Eragrostis pellucidus*
	Typha domingensis		*Eragrostis rigidifolius*
	Vigna monophyla		*Eragrostis tenuifolia*
	Vigna parkeri		*Floscopa glomerata*
	Viola abyssinica		*Harpachne schimperi*

	Zornia setosa		*Hyparrhenia collina*
			Hyparrhenia cymbarica
Polygalaceae	*Polygala sphenoptera*		*Hyparrhenia filipendura*
	Fallopia convolvus		*Hyparrhenia hirta*
	Oxygonum sinuatum		*Hyparrhenia rufa*
	Polygonum nakuruense		*Hyperthelia dissolute*
	Polygonum nepalense		*Imperata cylindrical*
	Polygonum pulchrum		*Leersia hexandra*
	Polygonum salicifolium		*Loudetia kagerensis*
	Polygonum senegalensis		*Microchloa kunthii*
	Rumex abyssinica		*Oplismenus hirtellus*
	Rumex bequaertii		*Panicum deustum*
			Panicum maximum
Portulaceae	*Portulaca oleraceae*		*Panicum pyramidalis*
	Portulaca quadrifida		*Paspalum auriculatum*
			Paspalum commersoni
Proteaceae	*Grevillea robusta*		*Paspalum scrobiculatum*
			Pennisetum cladestinum
Ranunculaceae	*Clematis brachiata*		*Pennisetum giganteum*
	Ranunculus multifidus		*Pennisetum polystachya*
	Thea sinensis		*Pennisetum purpureum*
			Pennisetum squamulatum
Resedaceae	*Caylusea abyssinica*		*Pennisetum trachyphyllum*
			Rhynchelytrum repens
Rhamnaceae	*Gouania longispiculata*		*Saccharum officinarum*
	Helinus mystacinus		*Setaria plicatilis*
	Scutia myrtina		*Setaria pumila*
			Setaria sphacelata
Rosaceae	*Alchemilla johnstonii*		*Setaria verticilata*
	Alchemilla kiwuensis		*Sorghastrum rigidifolium*
	Eriobotrya japonica		*Sorghastrum stiopoides*
	Prunus Africana		*Sorghum arundinaceum*
	Rubus pinnatus		*Sporobolus pellucidus*
	Rubus scheffleri		*Sporobulus pyramidalis*
	Rubus steudneri		*Stachys aculeolata*
			Thunbergia alata
Rubiaceae	*Coffea Arabica*		*Triumfetta annua*
	Galium spurium		*Zehneria scabra*
	Kohautia coccinia		*Zea mays*
	Oldenlandia herbacea		
	Pentanicia ouranogyne	**Rutaceae**	*Citrus limon*
	Pentas longiflora		*Tephrosia hildebrandtii*
	Richardia brasiliensis		*Torilis arvensis*
	Rubia cordifolia		
	Spermacoce princeae	**Solanaceae**	*Datura metel*
	Sphaeranthus bullatus		*Datura stramonium*
	Vangueria madagascariensis		*Lycoperscon esculentum*
	Verbena bonariensis		*Nicandra physalodes*
			Physalis peruviana
Sterculiaceae	*Dombeya burgessiae*		*Solanum aculeastrum*

	Dombeya torrida		*Solanum anguivi*
			Solanum incanum
Theaceae	*Camelia sinensis*		*Solanum nigrum*
	Themeda triandra		*Solanum schumannianum*
			Solanum teberosum
Tiliaceae	*Corchorus trilocularis*	**Typhaceae**	*Typha domingensis*
	Grewia bicolor		
	Grewia similis	**Ulmaceae**	*Celtis africana*
	Spermannia ricinocarpa		
	Triumfetta macrophylla	**Umbelliferae**	*Agrocharis incognita*
	Triumfetta rhomboidea		*Apium leptophylum*
	Tylosema fassoglensis		*Centella asiatica*
			Erythroselinum atropurpareum
Verbenaceae	*Clerodendrum myricoides*		*Hydrocotyle ranunculoides*
	Clerodendrum rotundifolium		*Oreoschimperella aberdarensis*
	Lippia javanica		
	Priva curtisiae		*Tragia brevipes*
	Verbena brasiliensis		
	Vernonia amygdalina		
	Cissus oliveri		
	Cyphostemma kilimandschari		
	Cyphostemma serpens		
	Rhoicissus tridentate		
Urticaceae	*Girardinia diversifolius*	**Zygophyllaceae**	*Trichodesma zeylanicum*
	Laportea alatipes		
	Pouzolzia parasitica		
	Urtica massaica		
	Vangueria infuasta		

Table 2: Some medicinal plants of Trans-Nzoia District

Botanical name (Family) and part(s) used
1. *Acacia* spp. (Fabaceae): Bark 2. *Aloe* spp. (Aloeceae): Leaves and tuberous roots 3. *Asparagus Africana* (Asparagaceae): Tuberous roots 4. *Balanites glabra* (Balanitaceae): Bark 5. *Carissa edulis* (Apocynaceae): Roots 6. *Catharanthus* spp. (Apocynaceae): Leaves 7. *Psidium guajava* (Myritaceae): Leaves 8. *Coleus* spp. (Lamiaceae): Leaves 9. *Commiphora* spp. (Burseraceae): Bark 10. *Erigeron* spp. (Asteraceae): Leaves 11. *Fagara* sp. (Rutaceae): Bark

12. *Ipomoea* sp. (Convovulaceae): Tubers
13. *Leonotis* spp. (Lamiaceae): Leaves
14. *Kigeria Africana* (Bignoniaceae): Bark and Fruit
15. *Melia volkensii* var. *keniae* (Meliaceae): Leaves and Bark
16. *Mimosa pudica* (Fabaceae): Leaves
17. *Omocarpum trichicarpum* (Fabaceae): Bark
18. *Pappea capensis* (Spindaceae): Bark
19. *Prunus africana* (Rosaceae): Bark and Leaves
20. *Rhoicissus tridentate* (Vitaceae): Tubers
21. *Sterculia africana* (Sterculiaceae): Bark
22. *Striga hermonthica* (Scrophuriacaee): Whole plant
23. *Synadenium campactum* (Euphorbiaceae): Leaves
24. *Urtica massaica* (Urticaceae): Leaves
25. *Warburgia ugandensis* (Canellaceae): Bark, Leaves and Fruit
26. *Ximeria caffra* (Olelaceae): Bark
27. *Ajuga ramota* (Hypericaceae): Leaves
28. *Opuntia* Sp. (Cactaceae): Fruits
29. *Vernonia* spp. (Asteraceae): Leaves
30. *Albizia* spp. (Mimosaceae): Bark
31. *Euphorbia hirta* (Euphorbiaceae): Whole plant
32. *Rhus* spp. (Anacardiaceae): Bark
33. *Aspilia* spp. (Asteraceae)
34. *Senna* spp. (Fabaceae)
35. *Terminalia* spp.(Compretaceae): Bark
36. *Centaurea mollis* (Asteraceae): Leaves

4.0 Conclusion

Based on the fact that many medicinal plants are threatened in Trans-Nzoia District conservation measures should be put in place to ensure survival of this important germplasm (Kanya et al., 2004). Participatory *in situ* conservation of medicinal plants though a fairly new concept in Kenya should be emphasized for application by land owners as it is practical and sustainable. To achieve this objective plant nursery of selected indigenous medicinal plants enlisted in Table 2 with known uses by traditional healers should be emphasized. The seedlings then should be supplied to farmers to plant either as hedge plants or along the farm boundaries to serve as wind breakers and a source of herbs for traditional healers and pharmaceutical companies. However, other modes of *in situ* conservation can be explored for plants listed in Table 1.

Acknowledgements

This work was supported by the U.S. A gency for International Development (Program on Biotechnology and Biodiversity Interface). The authors thank Mr. Daniel Mungai (EA) and Mr. Simon Mathenge (Department of Botany, University of Nairobi) for identifying the plants specimens.

References

Agnew, A. D. (1994). Upland Kenya wild flowers. A flora of the ferns and herbaceous flowering plants of upland Kenya. East African Natural History Society, Nairobi. Pp. 10-112.

Beentje, H. J. (1994). Kenya Trees Shrubsand Lianas. National Museums of Kenya, Nairobi. pp. 43-627.

Grieg-Smith, P. (1983). Quantitative plant ecology. Blackwell Scientific, Oxford, P. 8-10.

Kanya, I. J. (2004). Identification and quantification of Vegetation in the proximity of Maize in Trans-Nzoia District, Kenya. M. Sc. Thesis. Jomo Kenyatta University of Agriculture and Technology, Nairobi.

Kokwaro, J. O. (1983). Medicinal plants of East Africa. Kenya Literature Bureau, Nairobi.

Ochora, J. (2004). Establishing a herbal clinic (Kenya): Sharing innovative experiences – examples of development of pharmaceutical products from medicinal plants. Third World Network of Scientists Organization 10: 119-126.

Ochora, J. (2007). Traditional herbal pharmaceuticals: where does the secret lie? Proceedings of 2007 JKUAT Scientific, technological and Industrialization conference-"Galvanizing Science and Technology for Industrialization: Towards the Millennium Development Goals". 25th- 26th, October 2007, pp. 179-193.

Ochora, J., W. Gisesa, P. K. Njenga (2005). Does Traditional African Medicine and Practice in Kenya have a future? Proceedings of 2005 JKUAT Scientific, technological and Industrialization conference-"Leveraging Indigenous Products and Technologies through Research for Industrialization and Development". 27th- 28th, 2005, pp. 240-246.

Riley, B. W. and Brokensha, D. (1988). The Mbeere in Kenya: Botanical Identities and Uses. Vol. ii. University Press of America, Lanham.

William, J. S. (1996). Ecological census Techniques. Cambridge University Press, Cambridge.

ANTIMICROBIAL EFFECTS OF SELECTED HERBAL EXTRACTS ON MULTI-DRUG RESISTANT GRAM-NEGATIVE BACTERIAL STRAINS

M. M. Njire[1], N. L.M. Budambula[2] and J. N. Kiiru[3]
[1,2]Department of Botany, Jomo Kenyatta University of Agriculture and Technology, Nairobi Kenya
[3]Centre for Microbiology Research, Kenya Medical Research Institute, Nairobi Kenya
E-mail: nbudambula@yahoo.com

Abstract
The rise in antibiotic resistance has resulted in a decreasing number of fully active antimicrobial agents available to treat infections by multi-drug resistant (MDR) bacteria. This has necessitated a search for new antimicrobial agents. Herbal remedies may offer novel treatment options which elicit little or no transferred resistance if used in optimal concentrations. This study evaluated the antimicrobial properties of ten plants traditionally used as herbal remedies against 27 multi-drug resistant Gram-negative bacterial isolates. The herbal extracts were obtained through extraction with organic (methanol) and inorganic (water) solvents. Susceptibility of the test strains to conventional antibiotics was determined by the disc diffusion technique. Determination of the Minimum Inhibitory Concentrations (MIC) and the sub-lethal concentrations of the most effective extracts against the MDR strains was done by broth inoculation followed by colony count method. The effect of sub-lethal extract concentrations was done by a method modified from McMahon *et al*. (2007). Out of the ten plants, only *Warbugia ugandensis* was active against the MDR strains and its efficacy was significantly different from that of other plant extracts such as *Terminalia brownii, Azaridachta indica, Clausena anisata* and *Strychnos henningsii* ($p<0.001$). The root and bark methanol extracts from *W. ugandensis* were the most effective with an MIC of 42 µg/ml. Susceptibility of test strains to conventional antibiotics was not significantly different before and after habituation to sub-optimal extract concentration ($p>0.005$). Methanol extracts from the root and bark of *W. ugandensis* provide potential sources of effective antimicrobial compounds for further development of alternative safe antimicrobial products in form of chemotherapeutic agents or antiseptics. The optimization and standardization of operation procedures and methods of analysing the efficacy of herbal extracts demands serious consideration.

Key words: Multi-drug resistant (MDR) bacteria, Minimum Inhibitory Concentrations (MICs), Sub-Lethal Concentration (SLC)

1.0 Introduction

Antimicrobial agents have substantially reduced the threat posed by infectious diseases over a period of time since their discovery in the 1940s (Lewis and Ausubel, 2006). However, the escalation of multidrug resistance in bacteria in recent years has seriously jeopardized these gains. This has gained worldwide attention due to the high impact on public health. Increased usage of antimicrobial agents to treat bacterial infections has lead to the emergence of multi drug resistant (MDR) strains (Bonnet, 2004). Such strains are resistant to first line of treatments and also the more expensive second and third-line antibiotics. The high cost of such replacement drugs and the toxicological effects are prohibitive and are out of reach for many Kenyans. Furthermore, newer antimicrobials are losing their effectivity fast due to transfer of resistance markers from resistant to susceptible bacterial strains. This scenario has necessitated a search for new antimicrobial substances from other sources especially plants, which produce diverse chemical compounds with different biological activities (Lewis and Ausubel, 2006).

Plants form an integral part of life in many indigenous African communities as a readily and cheaply available alternative to allopathic medicines. Such plants have been found to cure urinary tract infections, gastrointestinal disorders, respiratory diseases and cutaneous infections (Somchit *et al.,* 2003), caused by bacteria often known to resist various classes of conventional antibiotics. Due to either limited availability or affordability of pharmaceutical medicines about 80% of the rural population in Sub-Saharan Africa (SSA) depends on traditional herbal remedies for primary health care (PHC) (WHO, 2002). Therefore, provision of safe and effective traditional medicines could become a critical tool to increase access to health care (WHO, 2002). It is expected that plant extracts exhibiting effective inhibition to microbial growth may provide less toxic, cheaper and more affordable alternatives for infection management. Moreover, the more efficient inhibition and lysis of bacteria resulting from the synergistic reactions of the active ingredients in plant extracts decreases the risk of progressively increasing antibiotic resistance (Miyasaki *et al*, 2010).

2.0 Materials and Methods

2.1 Test Strains

The test strains were selected from each of the following species; *E. coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa,* and *Salmonella typhi*, and their susceptibility patterns to different classes of antibiotics was determined. All the isolates had combined resistance to at least; two quinolones, two or more cephalosporins belonging to different classes, two aminoglycosides, one or two tetracyclines, and to one or more β- lactam/β- lactamase inhibitor.

2.2 Preparation of Plant Materials

The ten plants investigated in the study are those traditionally used for the treatment of bacterial infections by Kenyan communities (Table 1). The leaf, bark and root samples were harvested, packed in clean sterile manila papers, labelled with a voucher specimen and transported to the laboratory for analysis. The materials were oven-dried at 25°C and weighed every day until a constant weight was attained after which they were chopped and ground to fine powder using a motor grinder. The herbal extracts were obtained through extraction with organic (methanol) and inorganic (water) solvents.

2.3 Extraction of Plant Extracts

Warm water extraction was done to simulate the traditional decoction method of preparing herbal preparations. Sixty (60) g of the ground powder was soaked in 300 ml sterile distilled and deionised water at 50ºC for 1 hr, placed in an orbital shaker at 100 rpm for 24 h at 25ºC. The resulting elute was membrane-filtered and lyophilized into granules (LyoBeta range, Telstar, UK). Stock solutions were prepared by dissolving 0.4 g of the granules in 20 ml of deionised sterile distilled water while another set of a similar amount of preparations was dissolved in TE buffer (pH 8), and stored at -20ºC until further use.

Organic extraction was done using methanol. Sixty (60) g of the ground powder was soaked for 72 hr in a beaker containing 300 ml of methanol (Analytical Grade, 99.9%, Sigma-Aldrich, UK) and placed in an orbital shaker (Basic Model, Cole-Parmer, UK) at 100 rpm for 72 h at 25ºC. The resulting extracts were membrane filtered on a whatman paper number 1 then the filtrate concentrated at 50ºC using a vacuum rotary evaporator (Basic Model, Buchi, UK). In order to evaporate the methanol used as the extraction solvent, the concentrates were oven-dried at 25°C until a constant weight was attained. Excess methanol was evaporated by further air-drying the paste at 25°C until a constant weight was attained. Stock solutions of the methanol-free paste were prepared by dissolving 0.4 g in 20 ml of deionised sterile distilled water. Another preparation was dissolved in TE buffer at pH 8 as an alternative diluent. The preparations were stored at -20ºC until further use.

2.4 Pre-Screening of the Herbal Extracts for Antimicrobial Activity against Test Strain

Preliminary screening of the extracts for antimicrobial effect was done using *E. coli* J53 as the test organism. This strain has a defined genetic background and is susceptible to all conventional antibiotics except Sodium azide. A confluent lawn of the bacteria was prepared from a 0.5 MacFarland equivalent (approximately 10^6 CFU/ml) and placed in an incubator to dry after which 0.5 µl of the test extracts were point inoculated using a micropipette (Eppendorf, Hamburg, Germany). Other sets of preparations were made in a similar way and used for testing the efficacy at each of the following titres: 1 µl, 5 µl, 10 µl, 30 µl, 80 µl or 100 µl. Extract-free sterile distilled water and TE buffer (the diluents used for making the stock solutions of the test extracts), were inoculated in another set of these plates and used as negative controls. The plates were allowed to stand for at least 1 hr at room temperature for the extracts to diffuse at the point of inoculation before incubation at 37°C for 8 h. Observation of a clear zone on bacterial lawn at the point of inoculation of the extract was interpreted as evidence of inhibition of bacterial growth. The diameter of these zones were measured and recorded to the nearest size mm. The plants whose extracts exhibited an inhibition zone > 20 mm were selected for further testing of clinical isolates.

2.5 Determination of MICs and the Sub-Lethal Concentrations of the Herbal Extracts

Duplicate tubes containing 2 ml MH broth were prepared. To one set of these tubes, separate titres of the extract in the range of 5µl-120ul were added to separate tubes before a uniform inoculum of 10^6 CFU/ml of the test isolates was added to each tube. Negative controls were set in a similar way but using distilled water or TE buffer instead of the extracts. The preparations were incubated for 8 h at 37ºC with continous shaking at 100 rpm in an orbital shaker. The tubes were removed from the shakers and arranged sequentially with increasing concentration of the herbal extract titre added. The tubes were then assessed for evidence of bacteria growth by physical examination before streaking 1 µl of the preparations on MacConkey plates. The plates were then incubated for 8 hr and the colonies counts determined. The tube containing the lowest concentration at which no colonies were observed was identified and calculations done to determine the appropriate concentration of the herbal extract added. This concentration was identified as the MIC. The tube containing the preparation at which the last visible growth was observed was identified as the highest amount of extract that does not inhibit bacterial growth. This concentration was therefore identified as the highest sub-lethal concentration of the extract. This sub-lethal concentration was used as the reference concentration in the habituation experiment discussed in section 2.6 below.

2.6 Habituation to Sub-lethal Concentrations (Modified from McMahon et al., 2007)

Two sets of duplicate tubes containing 2 ml MH broth were prepared. The sub-lethal concentration of an extract was added and inoculated with approximately 10^6 CFU/ml bacterial cells of the clinical isolates or controls ATCC *E. coli* strains 25922 and J53. Negative controls were prepared using similar sets of bacterial preparations but instead of the extracts, deionised sterile distilled water or TE

buffer (pH 8) was used as blanks. All preparations were incubated for 72 h at 37ºC with shaking at 100 rpm after which colony counts were determined on MacConkey agar.

3.0 Results

3.1 Susceptibility Profiles of Test Strains to Conventional Antibiotics

All the 27 test isolates had combined resistance to at least; two quinolones, two or more cephalosporins, two aminoglycosides, tetracyclines, trimethoprim, and to at least one or more β-lactam/β- lactamase inhibitor. All isolates were resistant to ampicillin, 26 resistant to augmentin and only 8 isolates were resistant to cefoxitin (Table 2).

3.2 Pre-Screening of the Herbal Extracts for Antimicrobial Activity

The extracts from the 10 plants exhibited antibacterial effect and this depended on the plant species, part of the plant used, method of extraction and the volume of extract used (Table 3). Methanol extracts of *W. ugandensis* had a high antimicrobial effect even at titres as low as 0.5 µl from the 1 ug/ml of the plant extract preparation. There was a strong correlation between the amount of titre used and the zone of inhibition. Plants whose extracts of 100 µl produced an inhibition zone of greater than 24 mm were selected for further testing using the clinical strains and their MICs determined. The plants whose extracts met this criterion were: *W. ugandensis; T. brownii; A. indica; C. anisata* and *S. henningsii* (Table 3).

3.3 Characterization of Plants with Inhibitory Effect

The five plants whose extracts produced an inhibition zone ≥24 mm at 100 µl were further tested using clinical Gram-negative isolates. Although extracts from these plants had been tested to give inhibitory effect on *E. coli* J53, only methanol extracts from the root and bark of *W. ugandensis* were inhibitory to the MDR strains. Mean colony counts were obtained by averaging the colony counts for the duplicate sets at 100 µl of the extracts and their standard error (SE) obtained (Figure 1)**.** Inhibition of the other clinical isolates was similar to that of *E. coli* isolate, E_1.

3.4 Inhibitory Characteristics of *W. ugandensis*

Figure 2 indicates a comparison of inhibitory characteristics of different parts of *W.ugandensis.* Methanolic extracts from the bark of *W. ugandensis* exhibited better inhibitory properties than those obtained using water extraction ($p<0.001$). Similarly, the root extracts obtained using methanol from this plant were more effective than those obtained using water extraction method ($p < 0.01$), However, there were no significant differences in the methanolic and water extracts from the leaf ($p=0.298$). The inhibition characteristics of root and bark extracts obtained using methanol were not significantly different (t-test, $p = 0.908$)

Figure 3 shows the inhibition trend, MIC and sublethal concentrations of extracts from *W. ugandensis*. There was a gradual decrease in the number of colonies as the amount of titre (root and bark methanol extracts) increased. The colony counts from all other non-effective plants were not significantly different from those of the negative controls ($P > 0.05$) indicating that there was no inhibition. Colony counts decreased as methanol extract titres for the root and bark increased**.** Mean colony represents average colony counts for the duplicate sets at 100 µl of *W. ugandensis* extracts against a clinical *K. pneumoniae* isolate, K_1, and their standard errors (SE) (Figure 2)**.** Inhibition was similar for the other clinical isolates. There were no colonies at titres > 42 µl for the bark and root extracts. Therefore, the MIC for *W. ugandensis* methanolic root and bark extracts was 42.5 µg/ml. Consequently, the highest sublethal extract concentration for both the root and bark was thus 32.5 µg/ml **(**Figure 2**).**

Table 4 indicates mean inhibition zones of 15 conventional antibiotics against a *S. typhi* isolate, S3, before and after exposure to sub-optimal concentration (32.0 µg/ml) of *W. ugandensis* methanolic root extract. All the other clinical isolates had a similar trend. Bacterial strains exposed to a sub-optimum concentration of *W.ugandensis* methanolic extracts from the root and bark exhibited no significant differences in their antibiotic susceptibility profiles before and after exposure (t-test, $p > 0.005$).

4.0 Discussion

This study reports efficiency of extracts from *W. ugandensis* among the 27 Gram-negative bacterial isolates analysed. Varied antibacterial activity between the root/bark and leaf extracts observed are attributed to the different secondary metabolites found in these plant parts. The fact that the study also reports resistance by these isolates to different groups of antibiotics show that our extracts are a potential to offering effective, less expensive treatment options to diseases caused by these Gram-negative MDR strains. Characterization of specific anti-bacterial substances from the root and bark extracts will be an important step for potential development of novel anti-microbial agents against related strains.

On the basis of zones of inhibition, our results also revealed that extracts from five plants inhibited the growth of *E. coli* strain J53 indicating that such plants have a potential as anti-microbial agents and may require further testing for drug development. Other studies on medicinal plants (Thakurta *et al*., 2009; Osuga *et al*., 2006) have also realized a potential for these plants in the control of bacterial strains that exhibit resistance to conventional antibiotics.

The finding in our study that the MDR strains were only inhibited by methanol preparations from root and bark of *W. ugandensis* indicate that the extracts provide potential sources of effective anti-microbial compounds for further development of alternative safe anti-microbial products in form of chemotherapeutic agents or antiseptics. *W. ugandensis* has been used traditionally to treat bacterial infections and previous studies have reported its anti-bacterial activity. Crude extracts and purified compounds from *W. ugandensis* have been reported to be effective against *Mycobacterium tuberculosis*, *E. coli* and *Vibrio cholerae* (Mbwambo *et al.,* 2009). Wube *et al.* (2005), reported antimycobacterial activity of dichloromethane stem bark extracts against *M. aurum*, *M. fortuitum*, *M. phlei* and *M. Smegmatis.* The active constituents showed MIC values ranging from 4 to128 µg/ml compared to the antibiotic drugs ethambutol (MIC range from 0.5 to 8 µg/ml) and isoniazid (MIC range from 1 to 4 µg/ml). This closely corroborate with the results of our study in which methanolic root and bark extracts showed strong anti-bacterial activity with an MIC value of 42.5 µg/ml. Such an MIC indicates antibacterial potential comparable to that of conventional antibiotics like gentamicin (Tadeg *et al*., 2005).

Phytochemical investigations of this plant have identified drimane-type sesquiterpenoids as the main active components. Published work (e.g. Brooks and Draffan, 1969; Wube *et al*., 2005), has reported the presence of sesquiterpenoids in heartwood (e.g. ugandensolide, ugandesidial, warburgin and warburgiadione) and stem bark (e.g. muzigadiolide, deacetylugandensolide, cinnamolide, mukaadial, ugandensidial, muzigadial and waburganal). Flavonol glycosides and monoterpenes have been detected from the leaves of this plant (Manguro *et al.* 2003). Based on this information, this study did not carry out any phytochemical analysis but rather screened the crude extracts for their antimicrobial potential.

It is known that, in general, plant extracts are more effective against Gram-positive than Gram-negative bacteria (Suffredini *et al.,* 2006). However, our study showed that the Gram-negative organisms used were sensitive to the plant extracts even at low MICs. Therefore, these findings further support the idea that *W. ugandensis* may be an important source of compounds with broad-spectrum anti-microbial properties.

Results obtained with extracts from other plants including *T. brownii, A. indica, C. anisata, S. henningsii, Z. chalybeum, A. remota, T. indica, R. communis* and *A. Secundiflora* were significant in their own accord. From these results we note that although they are traditionally used in management of bacterial diseases, not all prescribed anti-bacterial medicinal plants may be effective against multi-drug resistant Gram-negative pathogens. The results may also suggest that the resistance observed for other plant extracts may partially be due to efflux pumps in the bacteria. Many efflux systems are multidrug transporters capable of expelling a wide spectrum of structurally unrelated drugs and anti-microbials, thus contributing significantly to bacterial multi-drug resistance (Veen and Konings, 2007).

The contrasting results of this study with those published by other investigators on anti-microbial activities of other plant extracts apart from *W. ugandensis* could be due to methodological discrepancy. For instance, Thakurt *et al*. (2007) reported significant antibacterial activity of *Azadirachta indica* leaf extracts against multi-drug-resistant *Vibrio cholerae*, while Tajamul *et al*. (2010) reported good anti-bacterial activity of *Ricinus communis* against pathogenic bacterial strains like *K. pneumoniae* and *E. coli.* This could be attributed to differences in bioassay techniques used and diluents used for extraction and elution. Thakurt *et al*. (2007) and Tajamul *et al*. (2010) used the disc diffusion technique to assay the anti-microbial activity of the plant extracts. Such standard anti-microbial susceptibility testing methods like the agar diffusion and Kirby-Bauer may result to misinterpretation of results especially for extracts with low anti-microbial activity or in cases where the active ingredient(s) may irreversibly bind to the paper discs (Das *et al.,* 2010). To overcome these drawbacks, the anti-microbial activity of the crude plant extracts was detected by performing viable counting following direct inoculation. This method allows for maximum action by the extract on the bacterial cells hence generating more reliable data. Besides the methodological approaches used by various investigators, the contrasting results could also be attributed to the locality of plant species, storage conditions, test strains used, and lack of appropriate positive and negative controls in some of these studies.

However, this study does not rule out the potential of such plants as agents for the treatment of infections caused by other agents. Besides, the plants may be effective while in combination with other medicinal plants or in combination with conventional antibiotics but further research to support this opinion is needed. Furthermore, some plants found not to have inhibitory effects *in vitro* may undergo enzymatical processing to make them effective *in vivo.* Others may become more potent in the presence of other components involved in immune response (Gonzalez-Lamothe *et al*., 2009).

In a previous study by McMahon *et al*. (2007), the continued use of tea tree oil as a herbal remedy in sub-optimal concentrations was shown to elicit the emergence of resistance to conventional antibiotics. The current study shows otherwise in which exposure of the MDR strains to sub-optimal extract concentration of *W. ugandensis* extracts had no effect on their susceptibility to conventional antibiotics and conjugative efficiency. Very little has been done to screen other herbal extracts for similar effects and it is not known if such herbal-elicited antibiotic resistance is transferable via conjugation or whether the presence of herbal agents stimulate or inhibit conjugal transfer of antibiotic resistance. Therefore, this study indicates the safety of using the plant extracts as herbal remedies in treatment of bacterial infections as they do not increase the selective pressure that potentiate bacterial resistance. In addition, this study provides useful data that will shed light on the use of the selected herbal extracts as alternatives to conventional anti-microbials.

5.0 Conclusion

The 27 under investigation strains were multi-drug resistant. Methanol extracts from root and barks of *W. ugandensis* exhibited better anti-microbial properties than other plant extracts tested. The

study established that the MIC of methanol extracts from the root and bark of *W. ugandensis* against the MDR gram-negative bacterial strains was 42.5 µg/ml. Exposure of test strains to sub-lethal extract concentrations of the effective extracts of *W .ugandensis* does not induce resistance to conventional antibiotics.

Acknowledgement
This work was funded by Jomo Kenyatta University of Agriculture and Technology, Centre for Microbiology Research (CMR), an arm of the Kenya Medical Institute (KEMRI) and the Vlaamse Interuniversitaire Raad (VLIR, PhD grant No. BBTP2007-0009-1086**).**

References

Bekele, T. (2008). Antidiabetic activity and phytochemical screening of crude extracts of Ajuga remota. Masters Thesis. Addis Ababa University, Ethiopia.

Brooks, C., J. W. and Draffan, G. H. (1969). Sesquiterpenoids of Warburgia species-II ugandensolide and ugandansidial (cinnamodial). *Tetrahedron.* **25,** pp 2887-2898.

Daniyan, S. Y. and Muhammad, H. B. (2008). Evaluation of the antimicrobial activities and phytochemical properties of extracts of *Tamaridus indica* against some diseases causing bacteria. *African Journal of Biotechnology,* **7** (14), pp 2451-2453.

Das, K., Tiwari, S. K. R. and Shrivastav, K. D. (2010). Techniques for evaluation of medicinal plant products as antimicrobial agent: Current methods and future trends. *Journal of Medicinal Plants Research*. **4**(2), pp 104-111.

Gonzalez-Lamothe, R., Mitchell G., Gattuso M., Diarra S. M., Malouin, F. and Bouarab, K. (2009). Plant antimicrobial agents and their effects on plant and human pathogens. *International Journal of Molecular Sciences*. **10**, pp 3400-3419.

Haraguchi, H. (1998). Mode of action of antimicrobial substances in plants. *Journal of Recent ResearchDevelopments in Agricultural and Food Chemistry.* **2** (1), pp 258-268.

Jaki, B. U. Franzblau, S. G., Chadwick, L. R., Lankin, D. C., Zhang ,F., Wang Y. and Pauli G. F. (2008). Purity-activity relationships of natural products: The case of anti-TB active ursolic acid. *Journal of NaturalProducts.* **71**, pp 1742-1748.

Krishnaiah, P. Devkota., Etienne, T. and Norbert, S. (2007). Anthraquinones from the stem bark of S*tereospermum zenkeri* with antimicrobial activity. *Journal of Phytochemistry*. **68**(11), pp 1595-1599.

Lewis, K. and Ausubel, F. M. (2006). Prospects of plant derived antibacterials. *Jouranal of Natural Biotechnology.* **24**, pp 1504-1507.

Manguro, L. O. A., Ugi, I., Lemmen, P. and Hermann, R. (2005). Flavonol glycosides of *Warburgia ugandensis* leaves. *Journal of Phytochemistry*. **64**, pp 891-896.

Mascolo, N., Izzo A. A., Borrelli F., Capasso, R., Di Carlo, G., Sautebin, L. and Capasso, F. (2004). Healing powers of aloes. **In**: Reynolds, T. (Editor). Aloes: The genus Aloe. CRC Press, Boca Raton, Florida, United States. pp. 209–238.

Mbwambo Z. H., Erasto P., InnocenT E. and Masimba P. J. (2009). Antimicrobial and cytotoxic activities of fresh leaf extracts of *Warburgia Ugandensis. Tanzania Journal of Health Research.* **11**(2).

McMahon, S. A., Blair, S. I., Moore, E. J. and McDowell, A. D. (2007). Habituation to sub-lethal concentrations of tea tree oil (Melaleuca alternifolia) is associated with reduced susceptibility to antibiotics in human pathogens. *Journal of Antimicrobial Chemotherapy.* **59**, pp 125–127.

Michel, M. and Gutmann, L. (1997). Methicillin-resistant *Staphylcoccus aureus* and vancomycin-resistant *Enterococci:* Therapeutic realities and possibilities. *Lancet.* **349**, pp 1901–1906.

Miyasaki1, Y., Nichols1 W. S., Morgan1, M. A., Kwan1, J. A., Van Benschoten, M. M., Kittell, P. E. and Hardy1, W. D. (2009). Screening of Herbal Extracts against Multi-Drug Resistant *Acinetobacter baumannii. Jouranal of Phytotherapy research*. **DOI**: 10.1002/ptr.3113

Olila, D., Olwa, O. and Opuda-Asibo, J. (2001). Antibacterial and antifungal activities of extracts of *Zanthoxylum chalybeum* and *Warburgia ugandensis*, Ugandan medicinal plants. *Journal of African Health Science*. **1**(2), pp 66–72.

Raji Y, Oloyo, A. K. and Morakinyo, A. O. (2006). Effect of methanol extract of *Ricinus communis* on reproduction of male rats. *Asian Journal of Andrology*. **8** (1), pp 115 – 121.

Somchit, M. N., Reezal, I., Nur I. E. and Mutalib, A. R. (2003). In vitro Antimicrobial Activity of Ethanol and Water Extracts of *Cassia alata. Journal of Ethnopharmacology.* **84***,* pp 1-4.

Suffredini, I. B., Paciencia, L. B., Nepomuceno, D. C., Younes, R. N. and Varella, A. D. (2006). Antibacterial and cytotoxic activity of Brazilian plant extracts – Clusiaceae. Mem Inst Oswaldo Cruz. **101**, pp 287–290.

Tadeg H., Mohammed E., Asres K. and Gebre-Mariam T. (2005). Antimicrobial activities of some selected traditional Ethiopian medicinal plants used in the treatment of skin disorders. *Journal of Ethnopharmacology.* **100,** pp 168-175.

Thakurta, P., Bhowmik, P., Mukherjee, S., Hajra, T., Patra, A., Bag, P. (2009). Antibacterial, antisecretory and antihemorrhagic activity of *Azadirachta indica* used to treat cholera and diarrhea in India *Journal of Ethnopharmacology*. **111**(3), pp 607-612.

Veen, H. W. and Konings, W. N. (2007). Drug efflux proteins in multidrug resistant bacteria. *Journal of Biological Chemistry.* **378**, pp 769–777.

Wube, A. A., Bucar, F., Gibbons S. and Asres, K. (2005). Sesquiterpenes from *Warburgia ugandensis* and their antimycobacterial activity. *Journal of Phytochemistry*. **66**(19), pp 2309.

Table 1: Plant species screened for their antimicrobial activity

Plant name	Plant family	Phytochemicals	Medicinal uses
Clausena anisata	Rutaceae	Flavonoids, tannins, saponins f	Stomach aches, whooping cough, malaria [f]
Aloe secundiflora	Aloceae	Phenolic compounds: chromone, anthraquinone or anthrone derivatives [k]	Disinfectant, treatment of Pneumonia, malaria, chest pains [k]
Strychnos henningsii	Loganiaceae	Alkaloids, saponins [j]	Mouth antiseptic, wounds, gastrointestinal disorders, malaria [j]
Ajuga remota	Lamiaceae	Flavonoids, tannins and sterols [i]	Bacterial infections [i]
Ricinus communis	Euphorbiacea	Alkaloids, saponins, tannins, phenolic [h]	Stomach aches, diarrhoea**,** boils, burns, worms, venereal diseases [h]
Zanthoxylum chalybeum	Rutaceae	Alkaloids and saponins [g]	Bacterial infections, malaria, colds, cough, toothache [g]
Tamarindus indica	Caesalpinaceae	Alkaloids, flavonoids, saponins, tannins [f]	Treatment of scabies, boils, diarrhoea, dysentery [f]
Warburgia ugandensis	Canellaceae	Sequiterpene dialdehydes: warburganal, muzigadial, polygodial [e]	Constipation, treatment of bacterial infections, stomach aches, coughs, muscle pains, weak joints, body pains [e]
Terminalia brownii	Combretaceae	Tannins, saponins, flavonoids, alkaloids [c]	Diarrhoea, stomach ache, fevers, hepatitis, colds [d]
Azadirachta indica	Maliaceae	Tannins, saponins, flavonoids, terpenoids, alkaloids [a]	Abdominal colic, treatment of wounds, boils, scabies, malaria, rheumatism [b]

[a]Krishnaiah *et al.* 2008; [b]Thakurta *et al.* 2009; [c]Osuga *et al*. 2006 ; [d]Zakaria *et al*., 2007; [e]Haraguchi, 1998; [f]Daniyan and Muhammad, 2008; [g]Olila *et al.* 2001; [h]Raji *et al.*, 2006; [i]Bekele, 2008; [j]Michel *et al*. 1999; [k]Mascolo *et al.,* 2004.

Table 2: Susceptibility of the 27 clinical Gram-negative strains to 15 conventional antibiotics

Antibiotics	Test Strains																									
	E_1	E_2	E_3	E_4	E_5	E_6	E_7	K_1	K_2	K_3	K_4	K_5	K_6	K_7	S_1	S_2	S_3	S_4	S_5	S_6	S_7	P_1	P_2	P_3	P_4	P_5	P_6
NOR	S	R	R	S	S	S	R	S	R	R	R	R	S	R	S	R	S	S	R	S	S	S	S	S	S	S	S
SMX	R	R	R	R	R	R	R	S	R	R	R	R	S	R	R	R	R	R	R	R	R	R	S	R	R	S	R
NA	R	R	R	R	R	S	R	S	R	R	R	R	R	R	R	S	S	S	R	S	S	R	R	S	S	R	R
TM	R	S	S	R	R	R	S	S	R	R	R	R	S	R	R	R	R	R	R	R	R	R	R	R	R	R	R
C	R	R	R	R	R	S	R	S	S	R	R	R	R	S	R	R	R	R	R	R	R	R	R	R	R	R	R
N	R	R	R	R	R	R	R	S	R	R	R	R	R	R	R	R	S	S	S	S	S	R	R	S	S	S	S
S	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	S	R	R	R	R	R	R	S
MN	R	R	R	R	S	R	I	S	S	R	R	R	R	R	R	R	R	S	R	R	R	R	R	S	R	R	R
CXM	R	R	R	R	R	R	R	S	R	S	R	R	R	R	S	S	S	S	S	S	S	S	R	S	S	R	R
CFM	R	R	R	R	R	R	R	S	R	S	R	R	S	R	S	R	S	S	S	S	S	S	R	S	S	R	R
CRO	R	R	R	R	R	R	R	S	R	S	R	R	R	R	S	R	S	S	S	R	S	R	R	S	S	S	R
ATM	R	R	R	R	R	R	R	S	R	R	R	R	S	R	S	R	S	S	S	S	R	S	S	S	S	R	R
FOX	R	S	S	S	S	S	S	S	S	S	S	R	R	S	S	S	S	R	S	S	S	R	R	S	S	R	R
AUG	R	R	R	R	R	R	R	S	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
AMP	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R

R: Resistant (intermediate phenotypes were recorded as resistant); S: Sensitive; **Antibiotics**: NOR: Norfloxacin; SMX: Sulfamethoxazole; NA: Nalidixic acid; TM: Trimethoprim; C: Chloramphenical; N: Neomycin; S: Streptomycin; MN: Minocycline; CXM: Cefuroxime; CRO: Ceftriaxone; ATM: Aztreonam; FOX: Cefoxitin; AUG: Augmentin; AMP: Ampicilin. Gram-negative clinical isolates of the species: *E. coli:* E_1-E_7; *K. pneumoniae:* K_1-K_7; *P. aeruginosa:* P_1-P_6; *S. typhi:* S_1-S_7

Table 3: Diameter of inhibition zones at 100 µl of the 10 plant extracts against E. coli J53

Plant	Plant Part	Diameter of Inhibition Zones (mm)	
		Methanol Extracts	Water Extracts
W. ugandensis	Root	30*	22
	Bark	28*	20
	Leaf	16	14
T. brownii	Root	16	17
	Bark	26*	22
	Leaf	27*	23
A. indica	Root	17	16
	Bark	25*	22
	Leaf	24*	21
C. anisata	Root	23	21
	Bark	25*	20
	Leaf	15	14
S. henningsii	Root	24*	20
	Bark	21	20
	Leaf	17	12
Z. chalybeum	Root	14	10
	Bark	17	10
	Leaf	15	11
A. remota	Root	15	10
	Bark	17	11
	Leaf	16	10
T. indica	Root	15	11
	Bark	16	11
	Leaf	17	10
R. communis	Root	11	10
	Bark	10	10
	Leaf	11	11
A. secundiflora	Leaf	10	10

Table 4: Mean inhibition zones of 15 conventional antibiotics against a S. typhi isolate, S3, before and after exposure to sub-optimal concentration of W. ugandensis methanolic root extract

	Antibiotics														
	NOR	SMX	NA	TM	C	N	S	MN	CXM	CFM	CRO	ATM	FOX	AUG	AMP
Mean zones of isolate S_3 before exposure	23	11	13	10	12	15	9	15	12	18	14	14	15	9	8
Mean zones of isolate S_3 after exposure	22	12	14	9	13	16	10	16	13	17	15	16	16	8	6
t-test (p value)	0.03	0.14	0.27	0.13	0.96	0.21	0.45	0.35	0.56	0.92	0.91	0.61	0.9	0.17	0.16

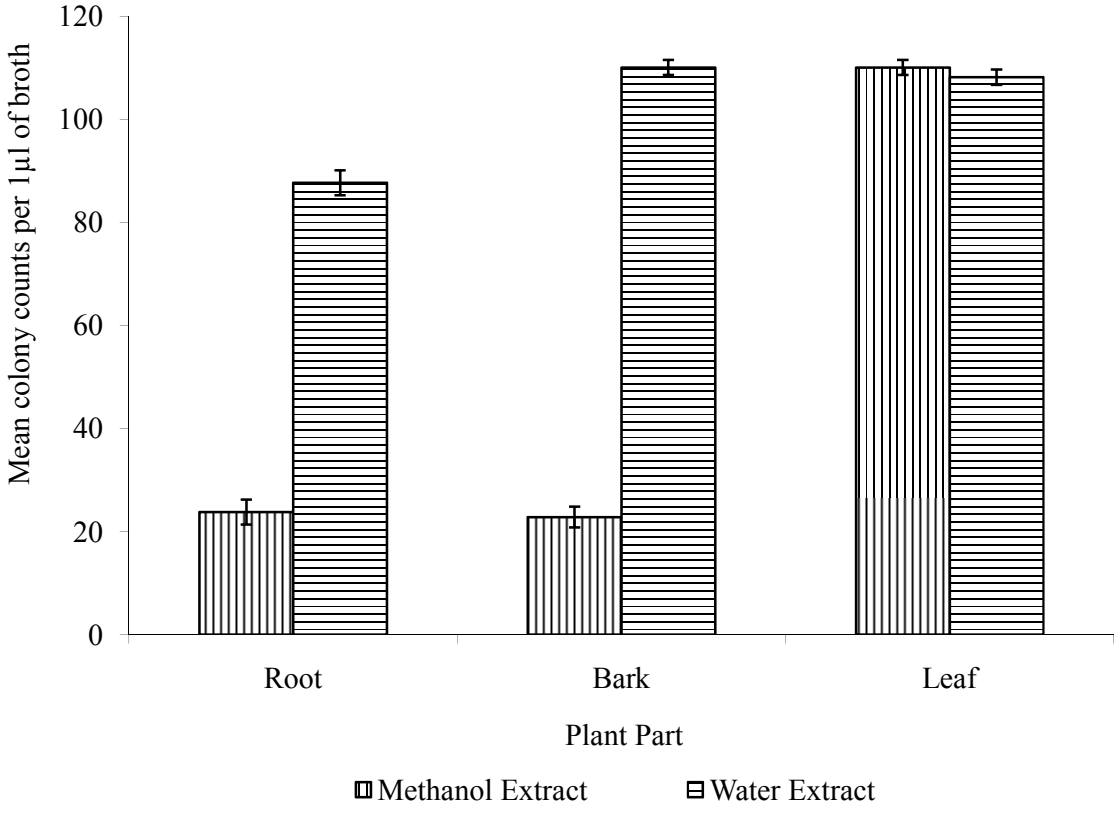


Figure 1: Differences in the effectiveness of water and methanol extracts of W. ugandensis against a clinical S. typhi isolate, S_1

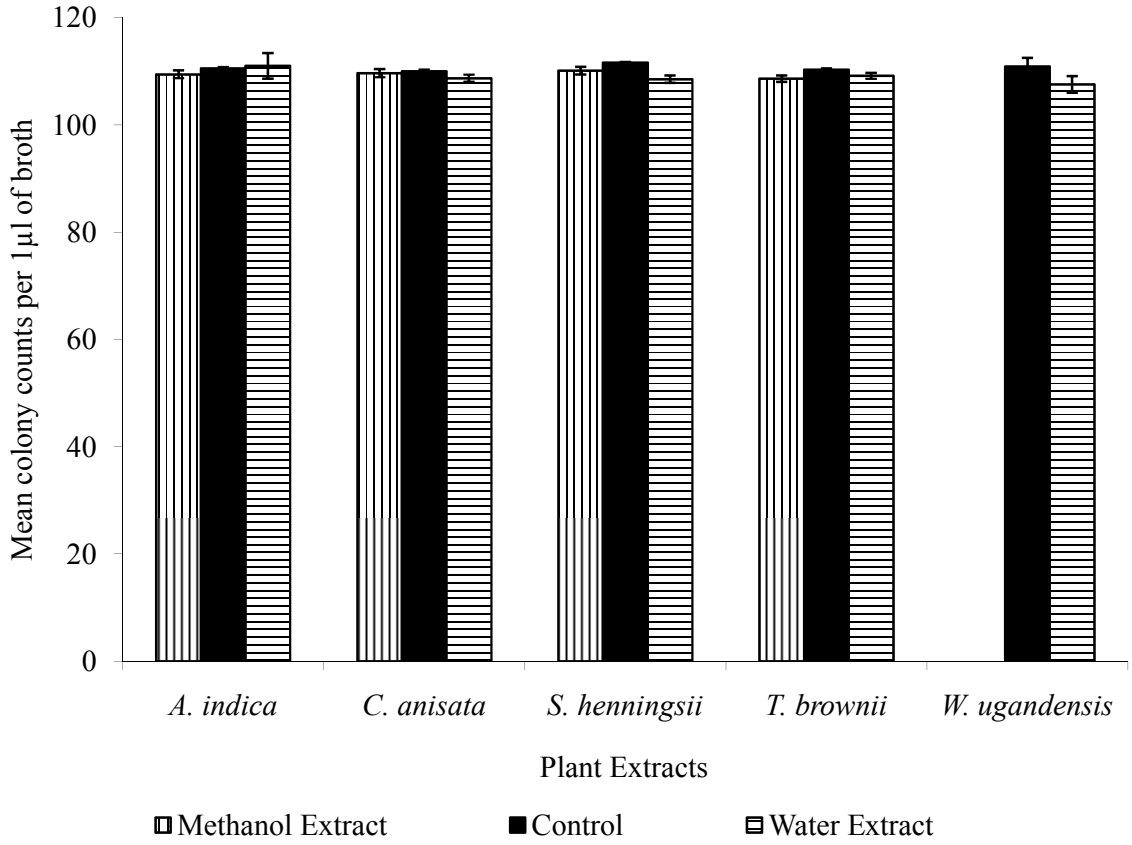


Figure 2: Inhibitory characteristics of the total extracts from five plants against a clinical E. coli isolate, E_1

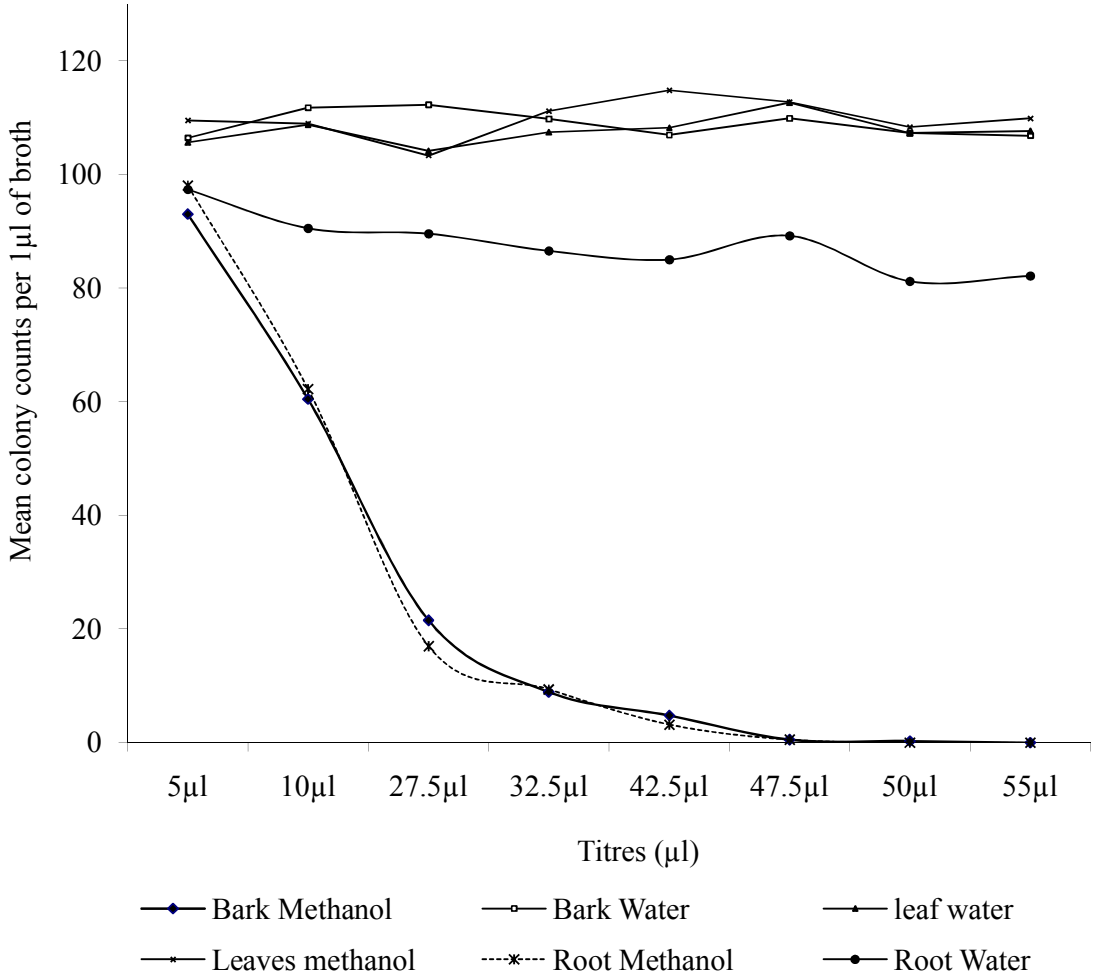


Figure 3: Growth characteristics of a clinical K. pneumoniae isolate, subjected to different titres of W. ugandensis extracts

POTENTIAL SKIN PATHOGENS ON SECOND HAND CLOTHES AND THE EFFECTIVENESS OF DISINFECTION METHODS

Y. M. Muthiani[1], V. N. Matiru[2] and C. Bii[3]

[1,2]Faculty of science, Department of Medical Microbiology, Jomo Kenyatta University of agriculture and technology, Nairobi, Kenya

[3]Kenya medical research Institute, Centre for Microbiology research, Nairobi, Kenya

Abstract

This study examined the pathogenic microbial levels in second hand undergarments and compared the effectiveness of disinfection methods used to reduce microbial load in the garments. Of special interest were pathogenic microbes in undergarments such as panties, bras, socks and towels which were collected from various flea markets. The study was planned following prior casual questioning of consumers to find out the most common decontamination methods used on these clothes. Clothe samples collected from the Gikomba second hand market were examined in a biomedical laboratory for evidence of high levels and types of pathogenic microbes and persistence of the pathogenic microbes that can be attributed to skin infection after decontamination procedures. Culture and biochemical methods were used for investigation. A variety of potential skin pathogens were isolated from unwashed second hand undergarments, socks and towels. Several bacteria were isolated including Methicillin-resistant *Staphylococcus aureus* (MRSA) and Methicillin-sensitive *Staphylococcus aureus* (MSSA). The fungi isolated from the unwashed clothes included *Scopulariopsis brevicalis*, *Geotrichum candidum*, *Scytalidium*, *Trichophyton mentagrophytes, Rhodotorula sp.*, *Cladosporium sp., Candida tropicalis*, *Candida glabrata* and *Aspergilus flavus.* Panties and bras had the highest count of both bacteria and fungi. The mycoflora was not limited to dermatophytes such as *Trichophyton* but other fungi exist such as *Alternaria alternata* which are pathogenic. In this study, the clothes were washed with grade 2 laundry bar soap. After washing there was a reduction in the bacterial ($t12 = 9.6$, $P < 0.001$) and yeast ($t12 = 3.5$, $P > 0.005$) plate counts but therefore was a no significant reduction in mold counts ($t12 = 1.1$, $P > 0.005$). The kill time for both Jik and Savlon against the MRSA isolates from clothes was 2 minutes. The concentrations of Omo used do not kill the MRSA isolates at 10 min. The study showed that second hand clothes are frequently contaminated by several pathogenic bacteria and fungi, which remain on these clothes even after washing with ordinary bar soaps. The information obtained from this study form a basis of advising consumers, public, Ministry of Health and health workers dealing with immunocompromised patients in nursing homes and hospitals. The findings from the study also reinforce the need for appropriate disinfection and conscientious contact control precautions.

Key words: Skin infections, second hand clothes, efficacy, disinfection methods

1.0 Introduction

The second hand clothes in Kenya are known as "Mitumba", a Kiswahili word meaning bale or bundle. Mitumba are imported by businessmen/women and charitable organizations. Scabies, pediculosis, and fungal infections are possible diseases that could be transferred through used clothes (The Kurdish globe, 2008 and Bandiaga *et al*., 2008). According to the (South Australia Public Health Fact Sheet, 2009) some of the risks associated with second clothing include **;** Tinea, Impetigo ,Scabies, Body lice ,Pubic lice /crabs, Head lice and Bed bugs.

The proportion of stalls devoted to second hand clothes has increased rapidly in most African countries (Hansen, 2000). In many studies, clothes have been found to be contaminated with chemicals and biotic factors. Existing studies on pathogenic microbes on clothes include microbial flora on ties (Dixon, 2000), Laboratory coats (Srinivasan *et al*., 2008) worn by doctors and students, lanyards (Kotsanas *et al*., 2008), nurse's scrubs and gowns (Pilonetto *et al*., 2004) used in hospitals and nursing homes. Skin infections are common in Eastern Africa countries which are deprived of the most basic of care for their skin disease (Donofroi *et al*., 1994).

Microorganisms in clothes are transmissible through sharing. Fomites have been shown to aid in the transmission of pathogens from one individual to another. A common fomite is bedding, where commonly employed materials, such as cotton, act as wicks to carry pathogens far from the initial contact point with human skin, particularly when moisture is present from sweat, semen, saliva, vaginal secretions, secretions from wounds and open pimples and spilled drinks . Thus, when sheets and pillow cases are changed, the deeper lying material (mattress, mattress cover and pillow) still harbor potential pathogens of the previous user(s). Furthermore, the next user particularly when moisture is introduced onto the scene can become infected by reverse wicking; i.e., moisture can draw deep lying pathogens back toward the surface of the bedding that is in contact with the user (Roberts *et al.*, 2008).

In a study by Nelly *et al*., 2000, the data indicated that staphylococci and enterococci can survive for extended periods of time on materials commonly worn by patients and health care workers and on various other fabrics in the hospital environment while Pilonetto *et al*., 2004, detected *S. aureus*, *Klebsiella pneumoniae* and *Acinetobacter baumanii* in hospital gowns. Neck ties worn by doctors at an intensive care unit produced heavy growths of coagulase negative staphylococcus on 2/5 ties tested (Dixon, 2000). This observation reinforces the need for more care with clothing. Studies have shown that various objects, such as utensils, toys, and clothes, can serve as vehicles for transmission of *Shigella* spp. (Islam *et al*., 2001). In a study by Nelly *et al*., (2001), *Candida, Aspergillus, Mucor*, and *Fusarium* which are associated with nosocomial infections in patients survived long periods on fabrics and plastics which are routinely used in hospitals. These survival results indicate the potential for various fabrics and plastics to serve as reservoirs or vectors for fungi.

Skin related infections have grown considerably in the community. The vast majority of these infections are transmitted through skin-to-skin contact, but a smaller yet significant portion is due to shared equipment (The Mercks Online Manual, 2009). Disinfection has been shown to reduce the number pathogenic microbes in disinfected clothes.

In this study undergarments from a popular second hand market were examined. The purpose of the study was to investigate the level and type of microbial contamination present on the second hand clothes in order to assess the risk of transmission of pathogenic microorganisms. Systematic examination was also undertaken on the survival of several clinical and environmental pathogenic microbial isolates on second hand clothes after several disinfection processes. The study employed culture methods for recovery of the pathogenic microbes on the second hand undergarments.

2.0 Materials and Methods

2.1 Study Area

This study was conducted in second hand cloth market in Gikomba which is in Kamukunji constituency. Gikomba is situated off Landies Road along Quarry road in Nairobi area and is the largest second hand goods market in Kenya.

2.2 Test Materials

Three samples were collected from each of the four categories:Towels, Bras, panties and socks.

2.3 Isolation of Bactrial and Fungi

Samples were obtained from the flea markets and placed in a sterile polyethylene bag. The entire area of sample was swabbed using a sterile cotton swab immersed in sterile water. The swab was then used for culture in Mannitol salt agar for Methicillin Resistant *Staphylococcus aureus* (MRSA). The plates were incubated at 37˚C for 48 hours and 30˚C for 5 days. Mannitol salt agar plates were examined for pathogens, including Methicillin-sensitive *Staphylococcus aureus* (MSSA) and Methicillin Resistant *Staphylococcus aureus*. Total microbial counts, expressed as colony-forming units (CFU), were recorded for each plate.

The entire area of sample was swabbed using a sterile cotton swab immersed in sterile water. The swab was used for culture in Sabourands Dextrose agar plates for yeasts. The plates were incubated at 30˚C for 5 days.

Direct imprints of 2 cm^2 swatches of all the samples were cut using a sterile scissors and cultured directly onto the middle of Mycosel agar plates for recovery of yeast and molds. The plates were incubated at 30˚C for 2 weeks to 4 weeks. After incubation the colonies on the surface were counted. Mycosel agar plates were examined for molds while Sabourands Dextrose agar plates were examined for yeasts. Total microbial counts, expressed as colony-forming units (CFU), were recorded for each plate.

2.4 Survival Test

The swatches were washed using grade 2 laundry bar soap and then dried after which isolation was carried out as described previously.

2.5 Identification of Pathogens

Staphylococcus aureus ferments mannitol and grows on mannitol salt agar well. Presumptive coagulase positive colonies form colonies surrounded by yellow colour while presumptive coagulase negative colonies are surrounded by pink colour. All yellow colonies on mannitol salt agar were picked and Gram stained to observe morphology.

The catalase test was used to detect the presence of catalase enzymes by the decomposition of hydrogen peroxide to release oxygen and water. One drop of hydrogen peroxide solution was be placed on a slide. A small portion of the suspect colony was spotted onto the centre of a slide. Presence of vigorous bubbling was observed occurring within 10 seconds, a hand lens was used when necessary. For this method, a positive result (was by observation of a vigorous bubbling indicated the presence of catalase) while a negative result (was by abservance of that bubbling).

Coagulase is an enzyme produced by *Staphylococcus aureus* that converts fibrinogen to fibrin. In the laboratory, it is used to distinguish between different types of *Staphylococcus* isolates. The test used rabbit plasma that had been inoculated with a staphylococcal colony. The tube was incubated at 37 degrees Celsius for 1-1/2 hours. If negative, incubation was continued up to 24 hours. A positve test was indicated by formation of clots while negative one was by absence of clots.

Coagulase positive colonies were subjected to oxacillin disc diffusion test to detect MRSA (Methicillin resistant*Staphylococcus aureus*) strains. A suspension of the isolate was prepared to 0.5 McFarland standard, then spread evenly onto Mueller-Hinton agar in a petri dish. Disks impregnated with 1 microgram oxacillin were placed onto the surface of the agar. After incubation, a clear circular zone of no growth in the immediate vicinity of a disk indicated susceptibility to that antimicrobial. Using reference tables, the size of zone was related to the MIC and results recorded as whether the organism was susceptible (S), intermediately susceptible (I), or resistant (R) to that antibiotic.

The colonies growing on the Sabourands Dextrose Agar plates were examined, noting the colony color, shape and texture. Lactophenol cotton blue mounts were made and Gram staining was done to rule out bacteria. Using the flow chart in identification manual, the genus was determined based on microscopic morphology. All growing colonies were plated on CHROMagarCandida for preliminary identification of *Candida* species. Yellow or pink yeast colonies were identified based on morphology after preparation of Lactophenol cotton blue mounts and using the identification key (Forbes *et al*.,2002).

Identification of molds was based on the examination of macroscopic characteristics such as colonial form, surface colour, production of pigments, growth rate and textures while microscopic features such as spore type and spore bearing cells were used for identification using a general key that has been established for identification of fungi(Campbell *et al*.,1996 and Forbes *et al*.,2002).

With a wire or needle bent at a 90 degrees angle a small portion of the isolated colony was cut.The portion was picked from a point intermediate between the centre and the periphery.The portion was placed on a slide to which Lactophenol cotton blue had been added. A coverslip was placed into postion and pressure applied gently. The slide was then observed using x40 magnification(Forbes *et al*.,2002). A small portion of clear vinyl tape, adhesive side down was pressed onto surface of the colony. The tape was removed and placed onto a drop of Lactophenol cotton blue on a slide which was examined microscopically(Forbes *et al*.,2002). A small portion of the colony was inoculated into Christensen urea agar and incubated under room temperature.

Time–kill experiments against isolates of *S. aureus* were undertaken using Jik™,Savlon™,Omo™ which are common household disinfectant, antiseptic and detergent respectively. Four strains of *S. aureus* were used for the kill time studies. Concentration of the disinfectants were prepared as follows:

(i) OMO™ - Lower concentration(0.0125g/5ml),Working solution(0.025g/ml) and upper concetration (0.05g/5 ml).
(ii) JIK™ – 0.5 ml:22 ml ,1 ml:44 ml and1 ml:10 ml
(iii) SAVLON™ -1ml:20 ml,0.5 ml:10 ml and 0.25 ml:5 ml .

The concetration of the disinfectants was determined from working solution with one above the working solution and one belowthe working solution. A suspension of the isolate was prepared to 0.5 McFarland standard. Each organism time-kill assay was performed separately. The timer was started and a sterile swab inserted into the tubes containing isolate. Tryptone soy broth was streaked at At time 0 and time points 2 minute, 4 minutes, 6 minutes, 8 minutes and 10 minutes. After overnight incubation, the plates were examined for growth or absence of growth at each concentration for each disinfectant and dertegent. The kill time was read at the concentration and time required to kill the test organism.

3.0 Results

3.1 Diversity of Microflora on Clothes Samples

A great diversity of bacterial colonies growing on Mannitol Salt Agar, which is a selective medium for recovering *Staphylococcus aureus. S. aureus* ferments mannitol and is able to grow on agar containing 70-10 0g/l sodium chloride thus is able to grow well on mannitol salt agar producing yellow colonies. Upon incubation, yellow, white cream, pink colonies were observed on the agar. Yellow colonies were picked and gram stained revealing, Gram positive cocci in clusters. Catalase test was used to distinguish between catalase negative (streptococci) and catalase positive (Staphylococci). Yellow colonies producing bubbles when 3% hydrogen peroxide was added were categorized as catalase positive (Table 1).

Table 1: Summary of bacterial isolated from clothes from Mannitol Salt agar

	Gram status and cell morphology
Bras	Gram positive cocci in clusters
	Gram positive cocci
	Gram negative rods
	Gram positive rods
Towels	Gram positive cocci
	Gram positive cocci in clusters
	Gram positive rods
	Gram negative rods
Socks	Gram positive cocci
	Gram positive cocci in clusters
	Gram positive rods
	Gram negative rods
Panties	Gram positive cocci
	Gram positive cocci in clusters
	Gram positive rods
	Gram negative rods

3.2 Mannitol Fermentation

Mannitol Salt Agar plate showing 24hr growth of mannitol fermentor (yellow) and non-mannitol fermentor (pink). Mannitol fermentation is biochemical characteristic used for the presumptive identification of *S. aureus* by the production of yellow pigments on Mannitol Salt Agar. Yellow colonies are therefore indicative of presence of *S. aureus* (Plate 1).

Plate 1: Mannitol fermentation

3.3 Effects of Washing

Bacterial counts before washing were found to be 824 C.F.U for panties. Panties and socks had the highest contamination with average plate count of 673.25 and 545 respectively. Towels and bras had the lowest plate counts with 470 and 412 respectively after washing. Table 2 and Figure 2 summarize the C.F.U of the different clothes before washing and after washing.

Table 2: Effects of Washing on plate counts in different cloth samples

SAMPLE	C.F.U BEFORE WASHING	C.F.U AFTER WASHING
1B	431	24
2B	405	66
3B	400	50
Average CFU of bras	412	46.67
1T	456	27
2T	450	255
3T	504	118
Average CFU of towels	470	133.33
1S	354	55
2S	481	19
3S	800	104
Average CFU of socks	545	59.33
1P	610	28
2P	780	44
3P	479	38
4P	824	61
Average CFU of panties	673.25	42.75

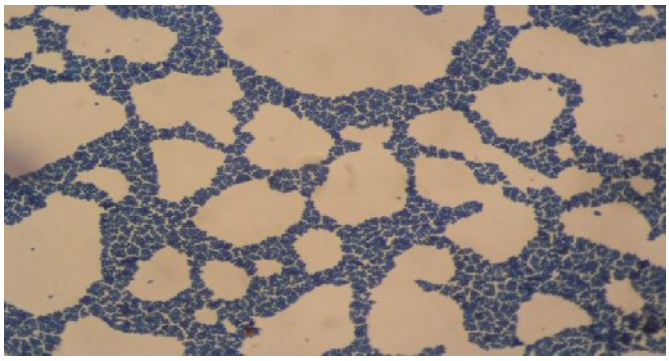


Plate 2: Photomicrograph of Gram Positive Cocci in clusters indicative of S. aureus

When the clothes were washed with laundry bar soap, socks and panties had the highest bacterial counts, followed by towels and bras (Figure 1).

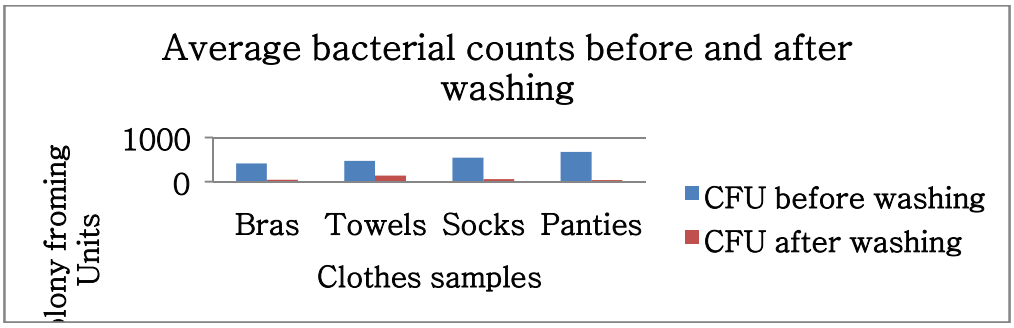


Figure 1: Average bacterial counts before and after washing

3.4 Methicillin Resistance Detection

S. aureus isolate from second hand clothes inoculated on Mueller Hinton plate, showing resistance to 1microgram Oxacilin disc (note arrow). MRSA Detection was done using the Kirby bauer disk diffusion method (Plate 3).

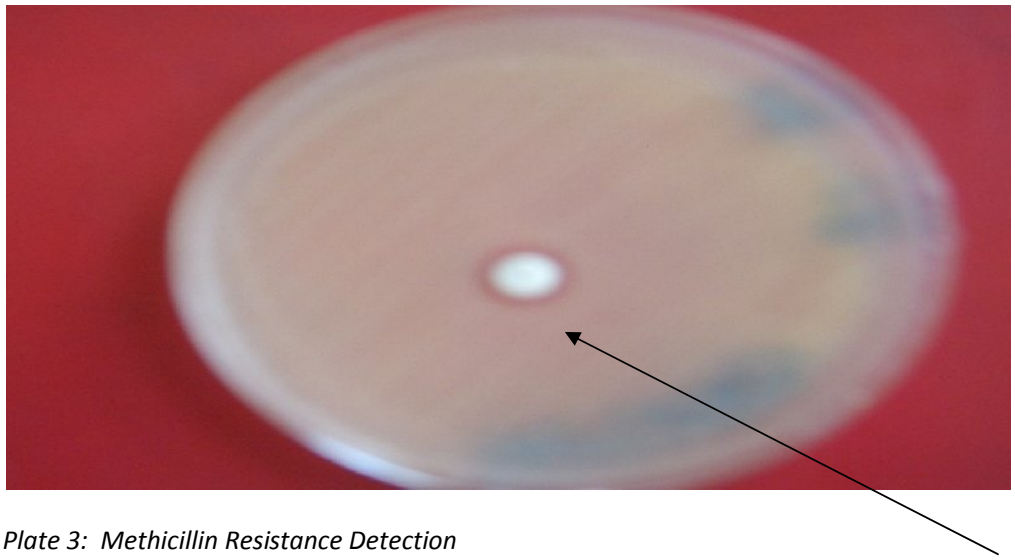


Plate 3: Methicillin Resistance Detection

Biochemical characterization revealed Coagulase positive *Staphylococcus* isolates from the second hand clothe samples. After using 1microgram Oxacilin disc 12(44.4%) of the coagulase positive *Staphylococci* isolates were found to be MSSA while 15(55.5%) were MRSA (Table 3 and Plate 3).

Table 3: Frequency of Isolation of MRSA in second hand clothes

Organism	Zone of Inhibition	Status
01	11mm	Resistant
02	10mm	Resistant
03	21mm	Sensitive
04	21mm	Sensitive
05	13mm	Intermediate
06	15mm	Intermediate
07	12mm	Intermediate
08	15mm	Intermediate
09	6mm	Resistant
10	17mm	Sensitive
11	18mm	Sensitive
12	16mm	Sensitive
13	12mm	Intermediate
14	6mm	Resistant
15	6mm	Resistant
16	11mm	Resistant
17	6mm	Resistant
18	10mm	Resistant
19	8mm	Resistant
20	16mm	Intermediate
21	8.5mm	Resistant
22	12mm	Intermediate
23	15mm	Intermediate
24	12mm	Intermediate
25	17mm	Sensitive
26	11mm	Resistant
27	6mm	Resistant

Key- Cut off point-Less than 11mm-Resistant 12-15 mm-Intermediate and >than 16 mm Sensitive while number 1-27 represents *Staphylococcus aureus* isolates.

3.5 Diversity of Fungi Iolated from Clothes

Molds isolated from second hand clothes were identified using lactophenol cotton blue mounts. These molds included *Scopularipsis brevicalis* (Plate 7), *Geotricum candicum*, *Scytalidium*, *Trichophyton mentagrophtes* (Plate 6), *Cladosporium* sp*., Paecilomyces* sp*., Altenaria alternata, Ramichhloridium mackenzei*, *Aspergilus flavus*, *and Rhizomucus pusillus* (Table 4). Table 4. Summarizes the different fungi isolated on Mycosel agar.

Table 4: Fungi isolated from the second hand clothes before and after washing

SAMPLE CODE NUMBER	COLONY FORMING UNITS	COLONIAL APPERANCE ON MYCOSEL AGAR	IDENTITY AFTER LACTOPHENOL STAINING
1P	4	Cream -colony	*Geotricum candicum*
2P	3	White powdery	*Trichopyton mentagrophtes*
		Olive green	*Cladosporium cladosporoides*
1P		Black	*Scytalidium*
3P	7	Green colony large	*Cladosporium cladosporoides*
4P	12	Sand brown colony	*Scopulariopsis brevicalis*
		Green-Blue colony	*Penicillium* sp.
		with white edge	
1S	-	-	Negative
2S	12	Black colony with	*Penicillium* sp.
		white edge ,furrows	*Aspergilus* sp.
3S	6	Black colony	Aspergilus sp.
1T	1	Sand brown colony	*Scopularipsis Brevicalis*
2T	7	White powdery	*Trichophyton*
3T	10	Blue green	*Penicillium*
			Aspergilus fumigatus

Yeast isolated from second hand clothes were identified using CHROMagarCandida including *Rhodotorula, Candida tropicalis* and *Candida glabrata*. Table 5 summarizes the different yeasts isolated, as well as Plates 4 and 5.

Table 5: The spectrum of yeasts isolated from second hand clothes

	C.F.U before washing	APPERANCE	IDENTITY on CHROMagarCandida	C.F.U	APPERANCE	IDENTITY CHROMagarCandida
1P	7	Pink colonies	Rhodotorula		NEGATIVE	
2P	18	White cream colonies Pink colonies	*Candida tropicalis* *Candida glabrata* *Rhodotorula* sp.	1	White cream colonies with shriveled black centre	Enlongated yeast non Candida
3P	4	Pink colony	*Rhodotorula* sp.	2	Small light pink colonies	*Rhodotorula* sp.
4P	4	White colonies	*Candida tropicalis*	1	Small colonies cream	*Candida tropicalis*
1S	16	White	*Candida tropicalis* *Candida glabrata*	4	Pink colonies	*Rhodotorula* sp.
2S	8	Pink Olive green	*Rhodotorula* sp. *Cladosporium* sp.	5	Large pink colony white	*Rhodotorula* sp. *Candida tropicalis*
3S		-		-	Negative	
1T	7	Pink colonies Olive green colonies	*Rhodotorula* sp. *Cladosporium* sp.	3	Pink colonies	*Rhodotorula* sp.
2T	15		Negative	-	Negative	
3T		-	-	-	Negative	
1B	4	Pink colonies	*Rhodotorula* sp.	2	small pink and white colonies	*Rhodotorula* sp. *Candida glabrata*
2B	10	white	Non-Candida yeast	6	Small colonies pink	*Rhodotorula* sp. *Candida tropicalis*
3B	7	Large pink colonies	*Rhodotorula* sp.	4	Large pink colonies White	*Rhodotorula* sp. *Candida glabrata*

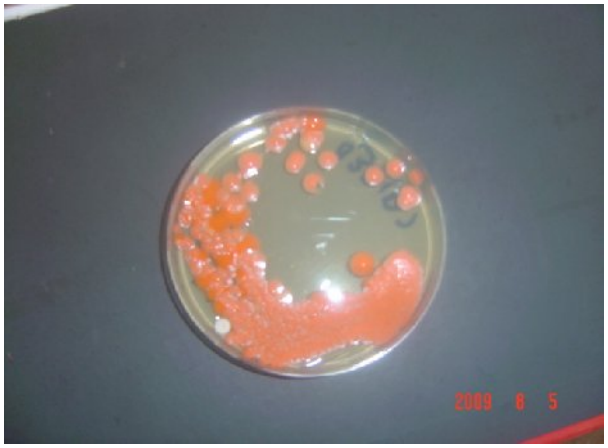


Plate 4: Orange colonies (Rhodotorula sp.) growing on Sabourands Dextrose agar

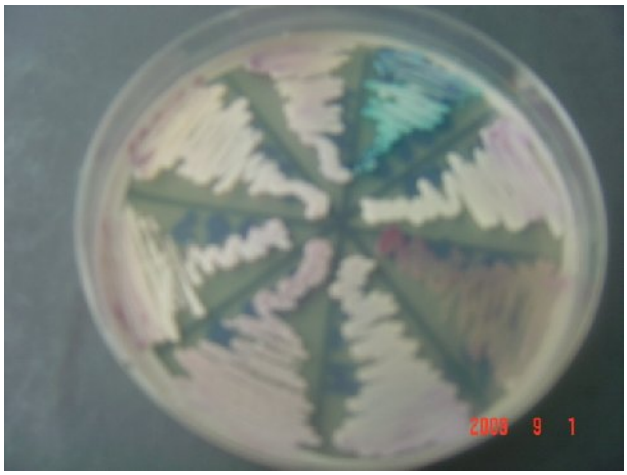


Plate 5: Colony morphology of different yeast species on CHROMagar Candida

Blue colour is usually indicative of *Candida tropicalis,* purple colour is indicative of *Candida glabrata,* pink colour is indicative of *Candida parapisilopsis* and pink colour is indicative of *Candida albicans* (Plate 5).

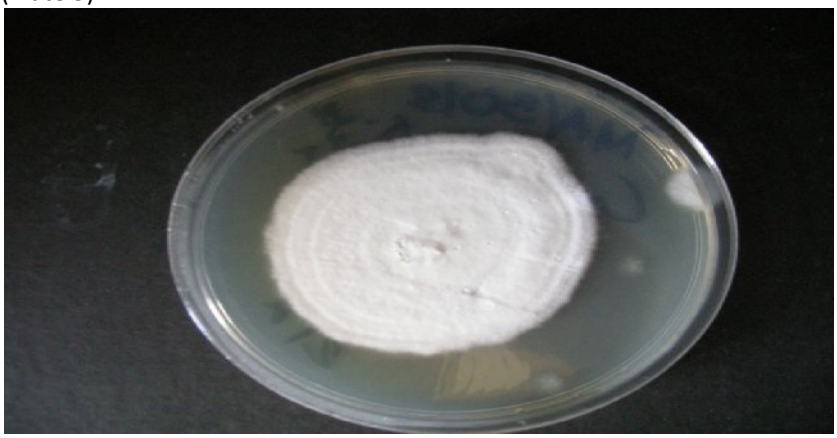


Plate 6: Trichophyton mentagrophytes (Table 4) isolated from towel sample

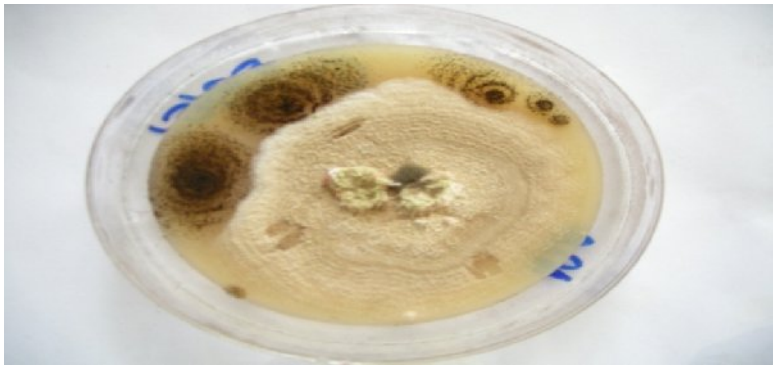


Plate 7: Scopulariopsis brevicaulis(brown colony). Note arrow

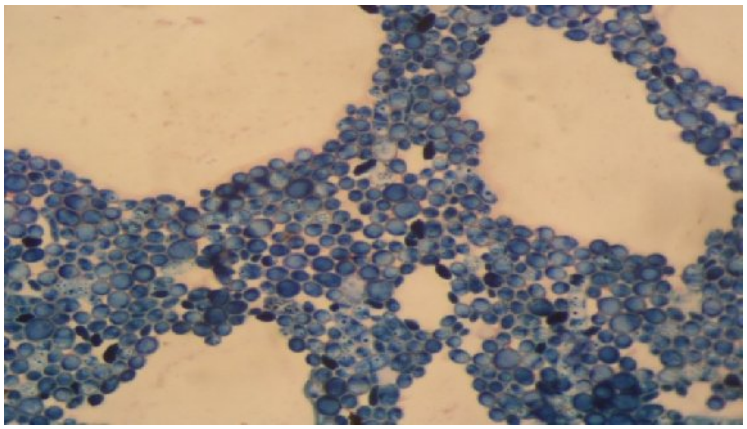


Plate 8: Photomicrograph of Candida glabrata

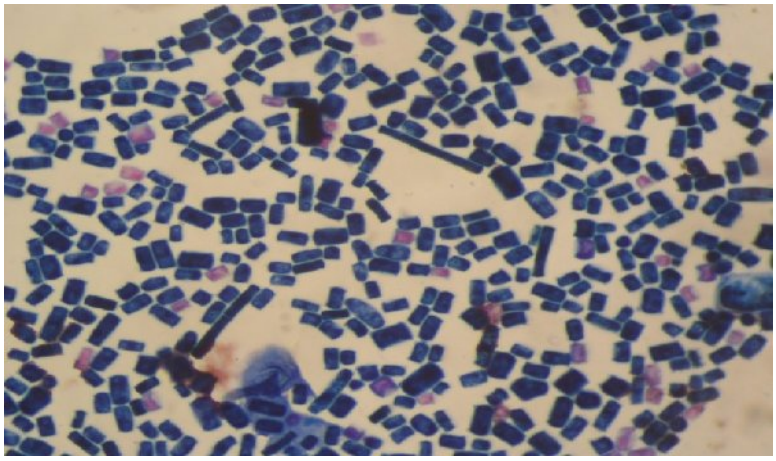


Plate 9: Photomicrograph of Geotricum sp

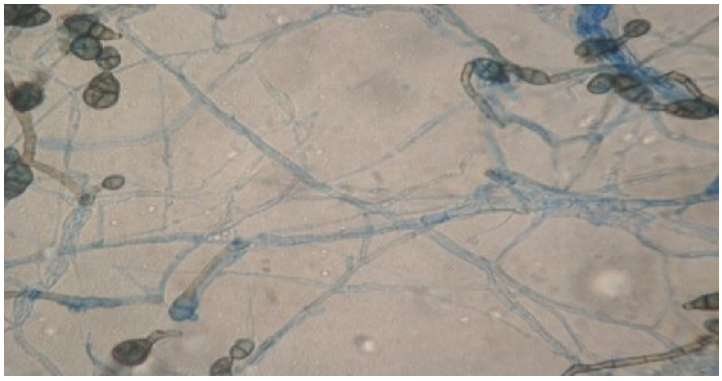


Plate 10: Photomicrograph of Altenaria alternate

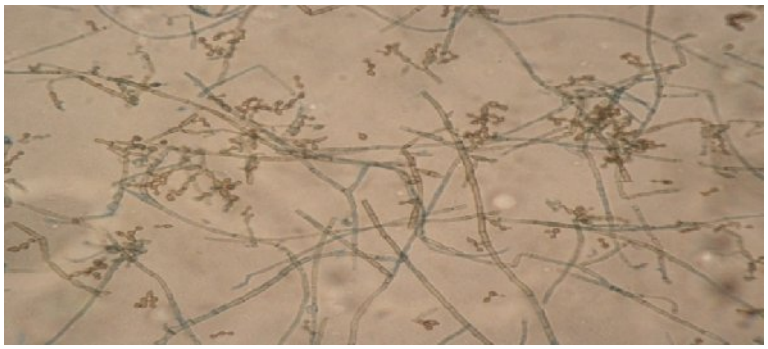


Plate 11: Photomicrograph of Cladosporium sp

Panties had the highest count of yeast with average count of 8.5 while bras had the lowest with an average count of 7 CFU as shown on Figure 2.

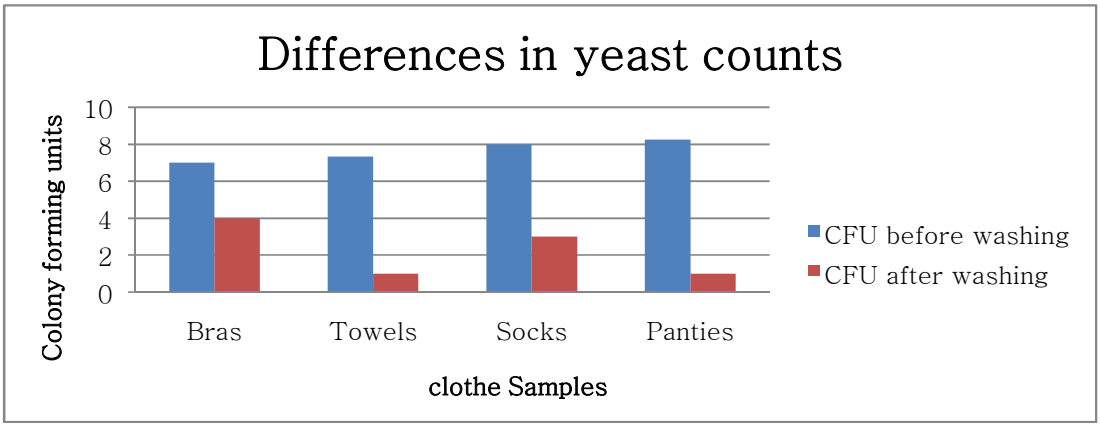


Figure 2: Differences in yeast counts before and after washing

Panties and bras had the highest count of molds with an average count of 6.5 and 6.3 respectively followed by towels and socks at 6 C.F.U per cm of the cloth before washing (Figure 3).

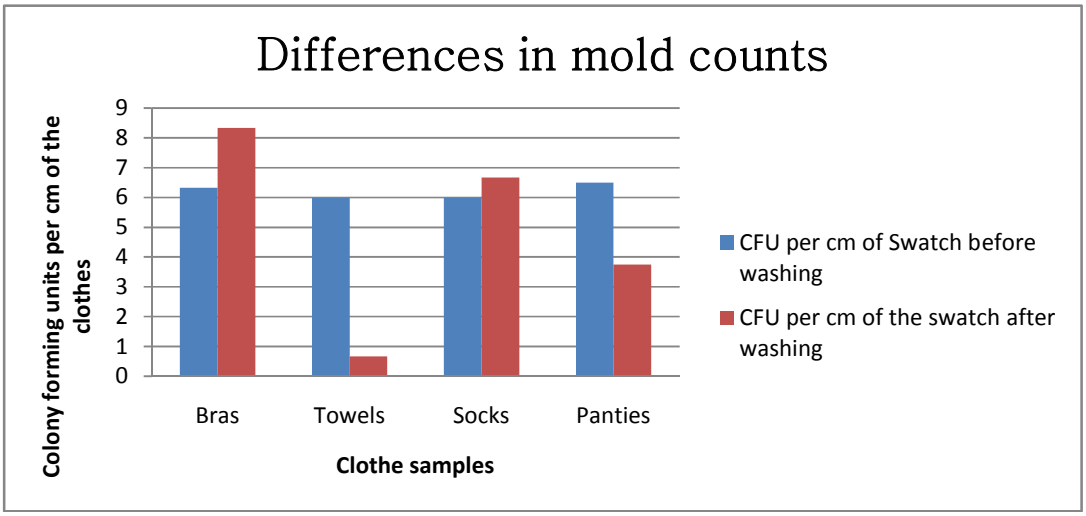


Figure 3: Differences in mold counts before and after washing

3.6 Kill Time Assay Results

The kill time of Jik was 2minutes at concentration range 1ml: 10ml (Jik: Distilled water) for all MRSA isolates tested. Growth was observed at 0minutes but no growth observed after 2 minutes (Plate 12).

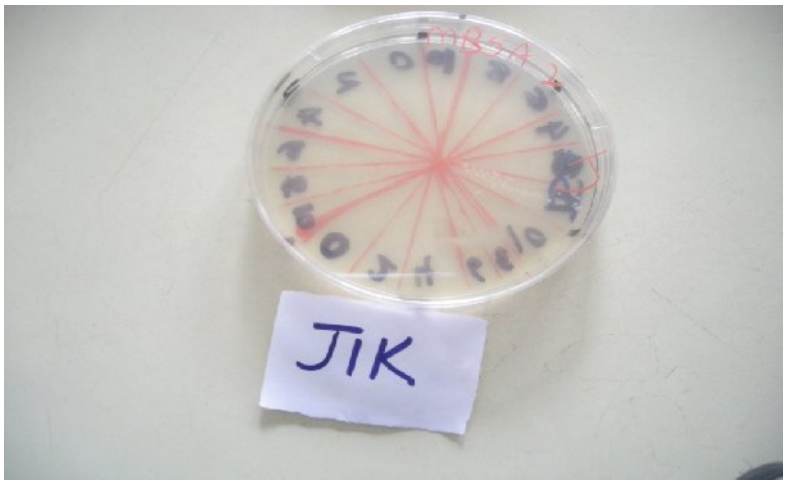


Plate 12: Determination of the Kill-Time of Sodium hypochloride(Jik™)

The kill time of Savlon was 2 minutes at 0.5 ml: 10 ml (Savlon : Distilled water) concentration for all the MRSA isolates tested. Growth was observed at 0 minutes (Note arrow) but no growth observed after 2minutes (Plate 13).

Plate 13: Determination of the Kill-Time of Savlon™

3.7 T-Test Analysis

The level of bacteria isolated reduced significantly after washing with the bar soap indicated by T-test analysis ($t_{12} = 1.1$, $P < 0.005$).

T stastic (1.1) is less than T–crtical value (2.2) therefore is no significant reduction in mold counts (t12 = 1.1, P > 0.005).

T- statistic (3.5) of differences in yeast counts before and after washing is greater than T–critical value (2.2). Therefore, was a significant reduction in yeast counts ($t12 = 3.5$, $P < 0.005$).

4.0 Discussion

This study demonstrated that second hand towels, bras, panties and socks were frequently colonized with bacteria such as *Staphylococcus aureus* including MRSA, MSSA which are of great public health concern. Detection frequencies of MRSA were noted to be higher in panties than in other clothes as shown in Figure 1. Staphylococci are widespread in the environment and can be cultured from clothing and virtually all environmental surfaces (Sattler *et al*., 2004). Because of the frequency of intimate contact with the previous owner skin and the fact that the undergarments come from people from all walks of life, it is reasonable to expect that these clothes are colonized with potentially pathogenic bacteria and fungi as demonstrated by the study. Staphylococci resist drying and can survive in dust and soil for years. They are tolerant of high temperatures; this capacity and resistance to drying allowing prolonged survival on fomites and clothing (Sattler *et al*., 2004). Coagulase-positive staphylococci are responsible for both sporadic infections and epidemics of varying extent. It causes superficial skin lesions such as boils, styes and furuncules; more serious infections such as pneumonia, mastitis, phlebitis, meningitis, and urinary tract infections; and deep-seated infections, such as osteomyelitis and endocarditis (Todar, 2008).

Methicillin resistance in *Staphylococcus aureus* was detected by Kirby-Bauer disk diffusion method. 12(44.4%) of the coagulase positive staphylococci isolates were found to be MSSA while 15(55.5%) were MRSA (Plate 2 and Table 3). Infections caused by methicillin-resistant *Staphylococcus aureus* (MRSA) cause significant morbidity and mortality (Synder *et al*., 2005). Because MRSA is resistant to all commonly prescribed beta-lactam antibiotics, these infections require treatment with alternative expensive antimicrobial drugs. Although Methicillin-resistant *Staphylococcus aureus* (MRSA) have been entrenched in hospital settings for several decades, MRSA strains have recently emerged outside the hospital, becoming known as community associated- MRSA((CA-MRSA) or superbug strains of the organism, which now account for the majority of staphylococcal infections seen in the Emergency Rescue or clinic (CDC Report,2003 and Sattler *et al*., 2004). Data from outbreaks of community-associated MRSA infection suggest that skin-skin and skin-fomite contact represent important and common alternative routes of acquisition of the skin infecting strain (Miller *et al*., 2008).

For staphylococci, the results are consistent with those of Nelly *et al*.,2000 and Loh *et al*.,2000 who reported that *S. aureus* can survive for long periods on hospital fabrics to become of epidemiological importance. In contrast, Scott and Bloomfield showed *S. aureus* surviving only 4 to 24 h on cloth; however, their inocula were low (102 CFU).

Majority of all of the clothes tested were cotton and polyester according to the clothes label. These materials are commonly used as undergarments and socks. Polyester and cotton fabrics are easily penetrated by common skin commensals. Takashima *et al*., 2004, found that polyester or acrylic fibers bound *S. aureus* and *P. aeruginosa* at high ratios (>80%), but cotton fibers bound them at low ratios (<10%). Nylon fibers bound *S. aureus* at low ratios, but *P. aeruginosa* at intermediate ratios. *Staphylococcus epidermidis* was found to adhere to fabrics much more so than *S. aureus*. The adherence of both *S. epidermidis* and *S. aureus* to fabrics increased as the content of polyester fibres in the fabrics increased. The attachment of E. coli to all fabrics was very low and was not affected by the fibre contents **(**Hsieh *et al*., 1986).

Survival of microbes on fomites is influenced by intrinsic factors which include fomite properties or microbe characteristics and extrinsic factors, including environmental temperature, humidity, etc. If

these microbes remain viable on surfaces long enough to come in contact with a host, they may only need to be present in small numbers to infect the next host (Boone *et al*, 2007).

Some of the fungi isolated from the clothes include *Scopularipsis brevicalis* (Plate 7), *Geotricum candicum*(Plate 9), *Scytalidium*, *Trichophyton mentagrophtes*(Plate 6)*, Rhodotorula sp.* (Plate 4), *Cladosporium sp., Candida tropicalis*, *Candida glabrata*, *Paecilomyces, Altenaria alternata*, *Ramichhloridium mackenzei*, *Aspergilus flavus*, *Rhizomucus pusillus* (Table 4). Panties and bras had the highest count of molds with an average count of 6.5 and 6.3 respectively followed by towels and socks at 6 C.F.U per cm of the cloth. This can be attributed to the high frequency of usage of the undergarments. After washing there was increase in CFU in bras and socks possibly due to dispersal of spores from one area of the clothe to a different area during washing which was then cut into swatch for isolation. Research shows that cotton fabric spreads spores of *Aspergilus* sp. better than other fabrics (Potera, 2001)

These data indicate that many of the fungi which are associated with fungal infections in patients can survive for long periods in clothes (Table 4).Several studies have been presented on the survival of yeasts on various surfaces, such as the survival study of *Aspergillus, Mucor, Fusarium, and Paecilomyces* on a variety of common hospital fabrics and plastics by Neely *et al*., 2001. Where comparisons are possible for the fungi data, my results agree with what is in the literature.

Yeast isolated included *Candida tropicalis*, *Candida glabrata, Geotricum and Rhodotorula* (Table 5). Panties had the highest count of yeast with average count of 8.5 while bras had the lowest with an average count of 7CFU. *Rhodotorula* was found to persist in the clothes even after washing the clothes with grade 2 bar soap as shown in Table 4. Nelly et al., 2000 quotes Blaschke-Hellmessen *et al*.,1986 study of yeast resistance to dryness, who found that those species of yeast that are more common in the environment, such as *Rhodotorula* spp., were more resistant to drying than yeast species that were more common on mucous membranes, such as *C. albicans*. Several *Aspergillus* spp. and *Penicillium* sp. were isolated in this study which could have been environmental species. These fungi have diverse clinical implication and cause superficial and systemic diseases with high fatalites. These results indicate the potential for various fabrics to serve as reservoirs or vectors for fungi because the fungi tested generally remained viable on these clothes even when they were washed. People with human immunodeficiency virus (HIV) or AIDS or other immune disorders and those undergoing chemotherapy are at higher risk as well, because they have a weakened immune system.

In this study, the clothes were washed with grade 2 laundry bar soap. After washing there was a reduction in the bacterial plate counts (t_{12} = 9.6, P < 0.001) (Table 2 and Figure 2). The grade 2 laundry bar soap may contain bactericidal or bacteriostatic compounds to the microbes harbored on the clothes. The concentration of bactericidal compound within the bar soap may be less than that of antiseptics such as Savlon. Thus, it is possible that spores of fungi would not be effectively killed by the bar soap. The differences in the microbes' counts among the four clothes types and the differences in CFU before and after washing were found to be different for all the test samples as shown in Figure 1, 2 and 3. This can be attributed to the different levels of exposure to contamination before washing among the clothes samples. Fumigation may have been carried out on clothes from the country of origin. Some of the clothes are also hanged in the open in the second hand market where the microbes can be killed by ultraviolet radiation from the sun. The frequency of usage and laundering by previous user, hygiene habits and their state of health e.g. shedding of pathogens from bodily fluid by sick user can be a factor to increased number in some clothes as compared to low number in clothes from healthy donor of second hand clothes.

The results of the Kill- Time Assay using Savlon and Jik indicated that the Kill-Time for both Salvon and Jik was 2 minutes at all the three concentrations used (Jik-0.5 ml: 22 ml, 1ml: 44 ml and1ml:10ml and Savlon-1 ml: 20 ml, 0.5 ml: 10 ml and 0.25 ml: 5ml) note Figure 4 and 5. When Omo was used for time kill assay all the MRSA isolates were not killed at 10 mins for all the concentration used which are lower concentration (0.0125g/5 ml), Working solution (0.025g/ml) and Upper concentration (0.05g/5 ml). Commonly used detergents such as omo and Laundry bar soaps contain enzymes and stain removal chemicals which may have bacteriostatic properties.

Jik is household bleach which contains Sodium hypochlorite (3.85%m/v) which has bactericidal activity to microbes thus it is used widely for disinfection. Chloride Releasing Agents (CRAs) such as hypochlorite are highly active oxidizing agents and thereby destroy the cellular activity of proteins. Deleterious effects of CRAs on bacterial DNA that involve the formation of chlorinated derivatives of nucleotide bases have been described (McDonnell *et al.*, 1999). Savlon contains n-propyl alcohol, chlorhexidine gluconate 0.3 g and Cetrimide 3.0 g (2.84 % m/v) which confer antiseptic properties to Savlon. Chlorhexidine is probably the most widely used biocide in antiseptic products, in particular in hand washing and oral products but also as a disinfectant and preservative (McDonnell *et al.*, 1999). Disinfection has been shown to reduce the number of pathogenic microbes in disinfected clothes. The data on the Kill-time assay showed that savlon and Jik are suitable for laundering clothes contaminated with these MRSA isolates. Despite the improvement of medical facilities for treating skin infection, there is an urgent need to disinfect the clothes with disinfectants to prevent infection.

5.0 Conclusion and Recommendations

Variety of both MSSA and MRSA potential skin pathogens were isolated from second hand undergarments, socks and towels and other clothes. The mycoflora is not limited to dermatophytes such as *Trichophyton* but other fungi exist such as *alternaria alternata* which are pathogenic. In this study, the kill time for both Jik and Savlon against the MRSA isolates from clothes is 2minutes. The concentrations of Omo used do not kill the MRSA isolate at 10 min. Although it is not easy to establish the precise role that second hand clothes may play in transmission of skin infections, this study adds to the growing data on clothing and equipment as potential vectors. Since the clothes are very popular. Regular disinfection of clothes using antiseptic and disinfectants such as Savlon and Jik may reduce bacterial pathogen contamination.

To prevent the spread of skin pathogens from the second hand clothes, several recommendations should be considered. One, consumers should wash second hand clothing with disinfectants and strong detergents such as Savlon and Jik as this reduce the microbial load of the clothes thus preventing infections; two, consumers should approach second hand undergarments with caution since this study has demonstrated that clothes have high bacterial counts. Pathogenic fungi are also found on these clothes and can these clothes serve as potential vectors of skin infection; three, research should be carried out to show direct correlation of skin infection with actual users of these clothes; four, Kill time studies for commonly used detergents should be carried for a longer time period (more than 10 minutes) to find out whether they can kill pathogens on clothes and lastly, the gap between 0-2 minutes can be checked to find out the appropriate/real time of exposure.

References

Alice, N. Neely and Matthew, P. Maley, **(**2000). Survival of Enterococci and Staphylococci on Hospital Fabrics and Plastic. *Journal of Clinical Microbiology*, Vol. **38**(2), pp 724-726.

Ali ,S. Murad, Thursday, 29 May 2008, Popular used goods at Langa Market, The Kurdish globe.

Arora and Arora, (2005). Medical Parasitology, CBS publishers, New Delhi, pp.196-198.

Becklin, N. L. (1998). Aseptics and aesthetic s of chlorine bleach: can its use in laundering be safely abandoned? *Am J Infect Control.* Apr; **26**(2), pp 149-51.

Betty, A. Forbes, Daniel, F. Sahm and Alice, S. Weissfeld, (2002). Baileys and Scott's 10th Edition Diagnostic Microbiology, Mosby publisher.

Blaser, M. J**.**, Smith, P. F**.**, Cody, H. J**.**, Wang W. L**.** and LaForce F. M**.** (1984). Killing of fabric associated in hospital laundry by low –temperature washing. *J Infect Dis.;* **149**(1), pp 48-57.

Brady, M. T., Evans, J. and Cuartas, J. (1990). Survival and disinfection of parainfluenza viruses on environmental surfaces. *Am J Infect Control.* **18**(1), pp 18-23.

Carlos, S. and Armando, C., (2004). Coagulase Positive Staphylococcal Infections (*Staphylococcus aureus*), In: Ralph D. Feign (Editor), Textbook of pediatric infectious diseases, 5th Edition, Saunders publishers, pp. 1099-1123.

Carol ,P., (2001). Clothing Spreads Spores, Environmental Health Perspectives, 109.

CDC report, Methicillin-Resistant *Staphylococcus aureus Infections* in Correctional Facilities --- Georgia, California, and Texas, 2001--2003 ,October 17, 2003 / **52**(41), pp 992-996.

Campbell, C. K., Johnson E. M., Philpot C. M. and Warnock D. W. (1996). Identification of pathogenic fungi, Public health Laboratory Services, London.

Charlotte, J., Louise, H. S. and Jens Adler-Nissen, (2001). Microbial survival and odor in laundry. *Journal of surfactants and Detergents* Vol.**4**(2), pp. 385-394.

Despina Kotsanas, Carmel Scott, Elizabeth E Gillespie, Tony M Korman and Rhonda L Stuart, (2008). What's hanging around your neck? Pathogenic bacteria on identity badges and lanyards *MJA*, **188** (1), pp 5-8.

Dixon, M., **(**2000). Neck ties as vectors for nosocomial infection. *Intensive Care Med*. **26**(2), pp 250.

Donfrio, L. M and Millikan, L. E. (1994). Dermatologic diseases of eastern Africa, Dermatologic clinics vol. **12**(4) pp.621-628.
Philip T., New York University, Personal communication (email), 2009 philip.tierno @Med.NYU.edu

Ferenczy, A., Bereron C and Richart R. M., (1989). Human papillomavirus DNA in fomites on objects used for the management of patients with genital human papillomavirus infections. Obstet GynecThe kill time of Savlon was 2 minutes at 0.5 ml: 10 ml (Savlon : Distilled water) concentration for all the MRSA isolates tested. Growth was observed at 0 minutes (Note arrow) but no growth observed after 2minutes (Plate 13). ol. ;**74**(6, pp 950-4.

Friedrich, F., The History of Biological Warfare Retrieved from http://media.wiley.com/product_data/excerpt/62/35273175/3527317562 Jan 2009.

Gerald M. and A. Denver Russell, **(**1999). Antiseptics and Disinfectants: Activity, Action, and Resistance Clinical Microbiology Reviews, p. 147-179, Vol. 12, No. 1

Graham, M. S., Kerri, A. T., Jon, P. F., Eli, N. P., Mary-Claire, R., Sandra, M. S., Giora, N., and Anthony, D. H., (2008). Detection of Methicillin-resistant Staphylococcus aureus and Vancomycin-resistant Enterococci by Healthcare Workers on Infection Control Gown and Gloves, *Infect Control Hosp Epidemiol.,* **29**(7*)*, pp 583–589.

Hambraeus, A**.**, Bengtsson, S**.** and Laurell, G**.** (1978). Bacterial contamination in a modern operating suite. 4. Bacterial contamination of clothes worn in the suite. *J Hyg (Lond)* **80**(2), pp 175-81.

Hsieh, Y. L., Merry, J. (1986). The adherence of *Staphylococcus aureus, Staphylococcus epidermidis* and *Escherichia coli* on cotton, polyester and their blends. **J Appl Bacteriol**., **60**, pp 535-44.

Islam, M. S., Hossain, M. A., Khan, S. I., Khan, M. N., Sack, R. B., Alber,t M. J., Huq, A. and Colwell, R. R. (2001). Survival of *Shigella dysenteriae* type 1 on fomites. *J Health Popul Nutr.*, **19**(3), pp 177-82.

Jon, L. R., Marvin, E. H. and Christopher, B. K. , Antifomitic device incorporating antimicrobial metals**.** Retrieved from http://www.faq.org/patent/inv/20174 on Jan 2009.

Karen, T. H., (2000). Salaula: The world of second hand clothes university of Cambridge publishers, pp.10.

Kenneth, T. (2008). *Staphylococci,* Todar's online textbook of bacteriology, Retrieved from (www.textbookofbacteriology.net) Jan 2009.

Kinabo, (2004). The Textile_Industry_and_the_Mitumba_Market_in_Tanzania. Retrieved from (http://www.tanzaniagateway.org/docs/Textile_Industry_and_the_Mitumba_Market_in_Tanzania.pdf.) Jan 2009.

Lee J., Wilkoff, Louise W., and Glen J. D. **(**1969). Persistence of Salmonella typhimurium on Fabrics, *Appl Microbiol*. August; **18**(2), pp 256–261.

Loh, W, Ng VV, Holton, J. **(**2000). Bacterial flora on the white coats of medical students. *J Hosp Infect*; **45,** pp 65-68.

Loren, G. Miller and Binh An Diep, (2008). Colonization, Fomites, and Virulence: Rethinking the Pathogenesis of Community-Associated Methicillin-Resistant *Staphylococcus aureus* Infection, *Clinical Infectious Diseases*; **46**, pp 752–760.

Marcelo, P., Edvaldo, A. R. R., Paulo, R. S. B., Daniela, B., Francine, C., Cristiane, S., Aguinaldo, N. and Iara, M, (2004). Hospital gowns as a vehicle for bacterial dissemination in an intensive care unit. ,*Braz J Infect* vol. **8** (3) Salvador.

Monica, C. (2000). District laboratory practice in tropical countries part 2, Cambridge university press. pp. 235-248.

Micheal, L. (1998). Skin and Wound Infections: An Overview, American Family Physician Vol. **57**, (10).

Neely, A. N., Orloff, M. (2001). Survival of Some Medically Important Fungi on Hospital Fabrics and Plastics. *J. Clin. Microbiol.* **39**, pp 3360-3361.

Rashid, S., Collins M., and Kennedy R. J. (1991). A study of candidosis: the role of fomites. *Genitourin Med.* April; **67**(2), pp 137–142.

Sékéné, B., Didier, R. and Philippe, B. (2008). Preventing and Controlling Emerging and Reemerging Transmissible Diseases in the Homeless. *Emerg Infect Dis.,* **14**(9), pp 1353–1359.

Srinivasan, M., Uma, A., Vinodhkumaradithyaa, A., Gomathi, S., and Thirumalaikolundusubramanian P., (2007). The medical overcoat-I it a transmitting agent for bacterial pathogen. *Jpn J Infect Dis.,* **60**(2-3). Pp 121-2.

Stephanie, A. B. and Charles, P. G. (2007). Significance of Fomites in the Spread of Respiratory and Enteric Viral Disease. *Appl Environ Microbiol*., **73**(6), pp 1687–1696.

South Australia Public Health Fact Sheet, Second hand goods: A guide for consumers Retrieved http://www.health.sa.gov.au/PEHS/PDF-files/ph-fs-consumers-secondhand.pdf. jan 2009.

Steinlechner, C., Wilding, G. and Cumberland, N. (2002). Microbes on ties: do they correlate with wound infection? *Ann R Coll Surg Eng,* (Suppl) **84**(9), pp 307-9.

Takashima, M., Shirai, F., Sageshima, M., Ikeda Okamato, Y., Dohi, Y.,(2004). Distinctive Bacteria binding property of cloth materials. *American journal of infection control,* **32**, pp 27-30.

The Mercks online manual**,** 2009, Skin infections retrieved from www.mercksmanual.org Jan 2009.

Webster's online dictionary, Definition of Second hand retrieved from http://dictionary.die.net/ Jan 2009.

WHO, 2005, Epidemiology and Management of Common Skin Diseases in Children in Developing Countries. Retrieved from http://whqlibdoc.who.int/hq/2005/WHO_FCH_CAH_05.12_eng.pdf).

Wilkoff, L. J., Westbrook, L. and Dixon, G. J. (1969). Factors affecting the persistence of *Staphylococcus aureus* on fabrics. *Appl. Microbiol.,* **17,** pp 268-274.

Wong, D, Nye, K, Hollis, P. **(**1991). Microbial flora on doctors' white coats. *BMJ*; **303,** pp 1602-1604.

Yoshinori ,T., Shoko, F., Daisuke, K., Tomonobu, T., Shuichi, T., Shoko, H., Michiko, K., Yusuke, K. and Yuko, T.**, (**1998). Warming and Sterilizing Towels by Microwave Irradiation. *Yonago Acta medica*, **41**, pp 83–88.

FRESH BLOOD SAMPLES VERSUS ARCHIVED SAMPLES IN HEPATITIS C VIRUS SCREENING: A COMPARATIVE STUDY

E. O. Odari[1], M. Ochwotto[2], N. L. M. Budambula[1], H. Nitschko[3] and J. H. Kimotho[2]
[1]Department of Botany, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[2]Kenya Medical Research Institute, Nairobi, Kenya
[3]Max von Pettenkofer-institut, Germany
E-mail: nbudambula@yahoo.com

Abstract
A low prevalence of Hepatitis C virus infection ranging from 0.1% to 0.9% has continuously been reported in the Kenyan population. Several studies have however concentrated on special groups like Intravenous Drug Users (IDUs) and blood bank samples, with no major study carried out in the general population. This study aimed at testing and comparing results of fresh and archived Hepatitis C infected samples obtained both from patients in Kenya and in Germany. Fresh and archived samples in Kenya were obtained from patients attending the liver clinic at the Kenyatta National Hospital and those stored at the Kenya Medical Research Institute (KEMRI), respectively. Fresh and archived samples from Germany were obtained from patients attending HCV treatment at the two main Ludwig Maximillian University hospitals in Germany and those stored at the Max von Pettenkofer Institute (MvPI)- Munich Germany, respectively. Freshly obtained samples were subjected to serological assays by Enzyme Linked Immunosorbent assay platforms (Ortho HCV 3.0 ELISA test system with an enhanced SAVe and AxSYM ELISA test system, for German samples and Murex ELISA test system, for Kenyan Samples) commonly used in each individual country before subjecting all the samples to a similar nested PCR diagnosis. All the archived samples had also been subjected to PCR diagnosis and confirmed positive at least once in the course of their storage. A total of 25 and 50 samples from Kenya and Germany, respectively, were tested and compared. All the 50 (100%) ELISA positive German samples were again confirmed PCR positive in the standardized PCR diagnostic system, whereas Kenyan samples realized varied results. Despite 100% (4 out of 4) detection by PCR on fresh samples, no detection, 0% (0 out of 21), was realized on the archived samples. These archived Kenyan samples could not also be detected by the available antibody based rapid detection kits. Based on the results realized with archived samples, whose conditions are deemed similar to the blood bank conditions in Kenya, this study asserts that although stored blood bank samples have continuously been used to estimate the prevalence of Hepatitis C infection in Kenya, this parameter may not be appropriate in estimating the true prevalence of this infection in the general population. Therefore, the study concludes and recommends the need to screen and determine the true prevalence of the infection using samples from the general population, since together with Hepatitis B, Hepatitis C infection are emerging as a major point of focus in blood transfusion screening in Kenya. The study further recommends that together with serological assays, Nucleic Acid based Techniques (NAT) should be employed in screening all freshly obtained blood before storage.

Key words: Hepatitis C virus, Fresh and archived samples, Nucleic Acid based Techniques, blood transfusion, blood bank samples

1.0 Introduction

The discovery of transfusion-transmissible infections (TTIs) has brought in a new era in the practice of blood transfusion worldwide with emphasis on two fundamental objectives, safety and protection of human life (Klein, 1995). Blood safety still remains a major concern in transfusion medicine in Kenya where bacterial and viral infections, including HIV, hepatitis B virus, that can be transmitted through blood transfusion still record a significant prevalence, with uncertain prevalence of hepatitis C in the general population. Human immunodeficiency virus (HIV), hepatitis B virus (HBV) and hepatitis C virus (HCV) are of great concern because of their prolonged viraemia and carrier or latent state. They also cause fatal, chronic and life-threatening disorders.

According to a UNAIDS report released in 2002, blood transfusion accounts for 5-10% of HIV infections in sub-Saharan Africa. Similarly, it is estimated that 12.5% of patients who receive blood transfusion in sub – Saharan Africa are at risk of post transfusion hepatitis (Fasola and Otegbayo, 2002). HCV plays an important role in the causation of chronic liver disease (Lesi *et al*, 2002). Muasya *et al.,* 2008, estimates a current prevalence rate of 0.2% to 0.9% among the general population in Kenya. This estimate seems to be supported by findings of Ilako *et al.,* 1995 who recorded a prevalence of 0.9% among volunteer blood donors. However, this may not reflect the true picture since no major survey on disease burden of HCV has been carried out in Kenya in recent times. It is also important to note that these estimates by Muasya and his group are contrary to his findings of a 22.2% prevalence rate among a cohort of drug users in Kenya.

Secondly, Kenya currently concentrates more on the screening for Hepatitis B, HIV and bacterial related sexually transmitted diseases, with little attention given to Hepatitis C virus in donated blood in blood banks. Further, HCV infection can proceed with no apparent clinical signs during the early phase of infection and is often diagnosed only by chance in asymptomatic population. Success of HCV treatment among those infected mainly depends on the infecting HCV genotype. Due to high costs involved in this type of treatment, many developing countries are yet to employ this treatment strategy, thus it is not assured whether all those who are diagnosed for HCV fully recover. Finally, Kenya borders Tanzania without any major cross-border movement health related restrictions. Tanzania has been shown to be among those countries with the highest HCV prevalence rate in the world (WHO, 1997) with Talatela *et al* (2007) recording a prevalence rate of 13.8% among children infected with HIV. These factors highlighted seem to suggest a higher prevalence rate of HCV in Kenya than the current rates, as assumed so far.

It is also clear that most studies on HCV prevalence use blood donors to report the frequency of HCV usually by anti- HCV antibodies and do not, normally, report follow-up HCV testing. It is important to note, however, that using blood donors as a prevalence source may underestimate the real prevalence of the virus because donors are generally from a healthier population stratum.

Following a 1994 study showing a high rate of transfusion-associated HIV (Moore et al., 2001), Kenya implemented WHO blood safety recommendations including: organizing the Kenya National Blood Transfusion Service (NBTS), stringent blood donor selection, and universal screening with fourth-generation p24 antigen and HIV antibody assays, aimed at reducing HIV post transfusion transmission, a strategy which has realized great achievements in HIV reduction (Basavaraju *et al.,* 2010). These stringent measures have not been so in the case of HCV screening, which has largely depended only on antibody detection. This study thus compared the rate of detection of HCV in freshly obtained and archived blood from Kenya and results obtained compared with a similar study with the infected German samples.

2.0 Materials and Methods

2.1 Study Design

This was a cross-sectional comparative study.

2.2 Study Sites

Fresh Kenyan samples were obtained from patients attending the liver clinic at the Kenyatta National Hospital, which is a national referral hospital in Kenya, whereas archived samples were obtained from those stored at the Kenya Medical Research Institute (KEMRI), an institute accredited for medical research in Kenya.

In Germany, the study was done using samples from patients attending HCV treatment at the two main Ludwig Maximillian University hospitals in Germany and those stored at the Max von Pettenkofer Institute (MvPI)- Munich Germany.

2.3 Ethical Considerations

The study in Kenya was done with the approval from the KEMRI ethical committee, whereas the study Germany was done with the permission from Max von Pettenkoffer – institute, an institute accredited for conducting medical research apart from routine diagnosis. In general, patients' confidentiality was completely maintained, with samples only identified with specially assigned identification numbers.

2.4 Laboratory Procedures

Kenyan samples

Antibody detection in samples

2.5 Rapid Kit Testing of HCV

All samples collected were detected for HCV antibody using a KEMPAC® rapid kit - a chromatographic immunoassay (CIA) for detection of HCV antibodies for hepatitis C in human serum. 60µl of the serum was added to the sample well and results read after 15 minutes. Two bands on the membrane indicated that the patient was positive for HCV-ab while one band indicated a negative result.

2.6 Screening for HCV Using ELISA Method

Samples were further analyzed by Murex (Abbott/ Murex Biotech Corp., Dartford, UK) ELISA kit as per the manufactures' instructions. Briefly; 180µl sample diluent was added to each well followed by 20µl of samples and the controls to the respective wells. The mixture was then incubated for one hour at 37^{o}C thereafter it was washed using automated ELISA washer. Immediately after washing 100µl of conjugate was added into each well, covered the wells and incubated at 37^{o}C for another one hour. After incubation the wells were washed and 100µl of the substrate solution added to each well. The plate was kept in a dark room for color development for 30 minutes at 37^{o}C after which a stop solution (1M of H_2SO_4) added to each well prior to reading the absorbance at 450nm using ELISA plate reader.

2.7 German Samples

2.7.1 Ortho HCV 3.0 ELISA Test System with an Enhanced SAVe

Blood samples were first tested using Ortho HCV 3.0 ELISA test system with enhanced SAVE (Ortho Clinical diagnostics, Johnson and Johnson, United Kingdom) in an automated system as per the manufacturer's instructions.

2.7.2 AxSYM HCV version 3.0

After evaluation with Ortho ELISA system, blood samples were further evaluated with a more sensitive AxSYM ELISA system (AxSYM system HCV version 3.0, Abbott, USA), also as per the manufacturer's instruction.

2.7.3 Detection for RNA by PCR

Samples from both study sites in Kenya and Germany were subjected to similar extraction and amplification protocols as follows;

2.8 Sample Extraction

Sample extraction was done using the High Pure Viral Nucleic Acid kit, version 3 (Roche applied science; Cat no. 11858874001 - Roche Molecular Biochemicals, Mannheim, Germany), according to the manufacturer's instructions.

Serum 200 µl was mixed with 200 µl of binding buffer supplemented with poly (A) and 50 µl proteinase K. These were mixed immediately and incubated for 10 minutes at 72°C. After incubation; further 100 µl of binding buffer was added to the mixture and separated using high pure filter tubes. During separation the mixture was washed with 500 µl of a special inhibitor removal buffer to get rid of PCR inhibitory contaminants. There were two wash steps using 450 µl wash buffer to either, remove bound nucleic acids, purification from salts, proteins and other cellular impurities, was done two times using. The bound RNA was finally eluted using 50 µl of elution solution. The purified RNA was then stored at -20°C.

2.9 Reverse Transcription

Purified RNA extracts were reverse transcribed to generate complementary DNA (cDNA). Reverse transcription was done using primers specific for 5'UTR (HCVN 02: 5' – gTg CAC ggT CTA CgA gAC C – 3' and HCVN 08: 5' –TAC TCA CCg gTT CCg CAg A – 3'). Reverse transcription was done using in-house protocol from the diagnostic virology department of MvPI. During this process, generated RNAs were linearized by incubating the RNA at 65°C for 10 minutes and then immediately subjecting the RNAs to a temperature of 4°C for a minimum of 10 minutes before further treatment.

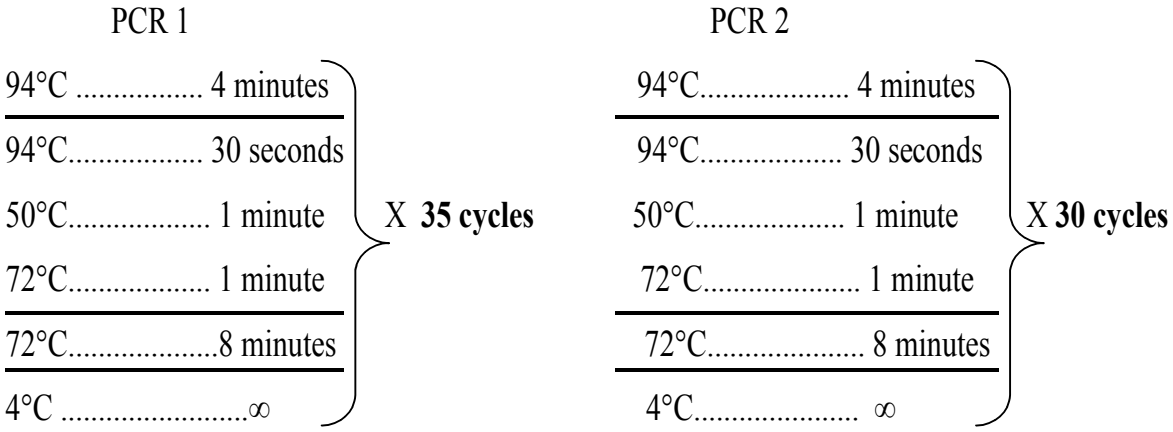
The master mix used in reverse transcription contained 4 µl of 5x Buffer, 2µl DTT, 2.2 µl of 10mM dNTPs, 1.6 µl of random primer and 0.2 µl of superscript. These were mixed with 10 µl of linearized RNA products generated, and incubated at 45°C for 1 hour, in order to generate cDNA which was then used to generate PCR products in a nested PCR reaction.

2.10 Nested PCR

cDNA products generated were amplified by nested PCR using two sets of in- house designed primers, both forward and reverse primers, as described in the in-house protocol for MvPI. Primers used included outer primers for the first PCR reaction; HCVN 01: 5' – ggC gAC ACT CCA CCA TRR A – 3' (forward primer) and HCVN 02: 5' – gTg CAC ggT CTA CgA gAC C – 3' (reverse primer). Inner primers for the second PCR reaction; HCVN 03: 5' – CAC TCC CCT gTg Agg AAC T – 3' (forward primer) and HCVN 04: 5' - CCC ggg gCA CTC gCA AgC A – 3' (reverse primer). Generated PCR products were then run on 2% gels to asses the products.

Generally, the composition of the master mix for PCR included 31.7 µl and 33.7 µl PCR water for the first and the second PCR reactions respectively. Other components used for both PCR reactions included 2 µl of 5mM dNTPs, 5 µl of 10x buffer with $Mgcl_2$, 3µl of reverse and forward primers and 0.3 µl of Taq polymerase.

Reactions for PCR 1 and PCR 2 were as follows;



3.0 Results

This study realized clear positive results with only 2 (8%) samples of all the 25 known positive Kenyan samples tested with the rapid antibody kits, commonly used for HCV screening in Kenya. Another 2 (8%) samples showed unclear results, indicated by the intensity of band formation (Plate 1a), whereas the remaining 21 (84%) could not be detected completely by these kits (Plate 1b).

When these samples were further subjected to Enzyme Linked Immunosorbent Assay, using Murex ELISA kit, the two positive and the two unclear samples by the rapid kits were detected making a total of 4 (16%) detections by this assay platforms. The remaining 21 (84%) samples that were not detected by the antibody rapid kits could not be detected by this ELISA kit. All the four samples positive by Murex ELISA kits were positive by RNA amplification (Plate 2). The other 21 samples that could not be detected by Murex ELISA and the rapid antibody kit could also not be amplified by PCR system (Plate 3). All the samples detected within this group were all fresh samples obtained in the course of the study. Percentile detection within the two groups of samples varied across the different assay platforms (Figure 1) used.

All German samples were detected by AxSYM and Ortho antibody ELISA kits used in the study. Of the total 50 samples, 9 (18%) could not be amplified by PCR despite high optical density values realized with AxSYM ELISA kit. These samples were classified as PCR negative - Antibody positive samples (Figure 2).

The remaining 41 (82%) were both positive by the ELISA kits as well as by PCR, and categorized as PCR and Antibody positive (Plate 4a). They included 5 samples that had freshly been obtained during the study (Plate 4b).

It was also realized that all the archived samples had viral loads above the suggested 260,000 IU/Ml theoretical threshold limit of detection for most HCV ELISA kits (Turke *et al.,* 2008). Except for only two samples, all other samples had the viral loads ranging from 300,000 to 7.5 million IU/ml, despite the fact that some samples had been in the archives for slightly more than 3 years, with the freshly obtained samples ranging from 8.9 to 29 million IU/ml. This study did not however realize any direct correlation between the viral loads and the optical signals generated for these samples, as some samples with viral loads of 40,000 IU/ml (which had stayed for 2 years in the archives) giving higher signals than those samples recently obtained and whose viral loads were high (Figure 3).

The study further assessed the differences in viral load measurements for four samples, immediately after thawing from -70°C and after exposure to room temperature for 24 hours. These samples were divided into 2 vials each. One vial for each was put back in the freezer at -70°C immediately while the next vial was exposed for 24 hours at room temperature, re-frozen for another 24 hours at -70°C before viral loads for all the vials, both frozen and exposed were measured. The study realized a reduction in viral load measurements for all the exposed vials across all the samples, with 2 samples undergoing 1 log reduction in viral loads as summarized in Table 1 and shown in Figures 4.

4.0 Discussion

All archived Kenyan samples could not be detected either by rapid, ELISA or even by PCR during this study, despite the fact that these samples had been categorized and archived as HCV positive samples. Despite the fact that freshly obtained samples were detected easily by antibody ELISA and by PCR amplification, two of these samples produced unclear results with rapid antibody test kits, which are deemed fast, affordable and easily available for HCV diagnosis. Most of these archived samples had previously been obtained from samples donated for blood bank from various regions in Kenya. These findings have major implications not only for HCV routine diagnosis but mainly for screening of blood intended for transfusion.

When compared to similar HCV positive samples obtained from archives in Germany, German samples could easily be detected by the ELISA systems commonly used in HCV diagnosis in Germany. These samples could also be amplified by PCR, which was not the case with archived samples from Kenya, despite the fact that a similar protocol for diagnosis was used for both samples. This finding in failure of detection for archived Kenyan samples generates various scientific arguments.

One argument could revolve around the possibility that after all, the samples could have been negative from the beginning and thus been a result of false positive samples mistakenly archived as HCV positive samples, leading to wastage of blood that could have easily been used to save lives. This argument may be supported by various observations based on the fact that most kits of HCV used in Kenya, are not evaluated using Kenyan isolated strains. This fact has resulted in continuous generation of conflicting data depending on the screening kit used with some kits reported to pick false positives (Tess *et al.,* 2000). In this study, however, a similar ELISA assay platform (Murex kit) that was used for detection of Kenyan samples has continuously been used for HCV detection, apart from the rapid kits. Similar protocols for HCV diagnosis, used here, have also been used in various studies involving Kenyan samples, non conflicting positive results generated (Karuru *et al.,* 2005; Muasya *et al.,* 2008; Muasya 2009). Further, the number of archived samples was also too large to warrant any false positive results by any assay platform.

Genotype variation within different areas of the world could be another argument for the different observation noted especially between the German and Kenyan samples. However, in this study, all German PCR positive samples were genotyped and others sequenced. Genotypes 1 to 4 were identified (data not published), this was attributed to the fact that Munich is a cosmopolitan city, hence this possibility. Since other studies (Muasya *et al.,* 2008) identified mainly genotype 1a and 4 to be prevalent among Kenyan samples, the fact that these genotypes were identified among the German samples, is a reason enough to rule out this line of argument.

Another argument would be based on the fact that unstable temperatures lead to a reduction in HCV RNA detection (Busch, 1992). Frequent thawing and freezing could therefore have contributed to a reduction in the levels of RNA eventually reaching below the threshold levels of detection. During the study, it was realized that when some of the positive samples were subjected to a room temperature for 24 hours then frozen again at -70°C for another 24 hours, a reduction in the viral load was observed in all the samples. In two samples, there was up to one log reduction after the 24-

hour exposure. This further supported this finding by Busch that a prolonged storage at room temperature resulted in a reduction in detectable HCV RNA concentration of more than 3 log, whereas freezing and thawing caused a half – log reduction (Busch, 1992). In their study Busch and colleagues (Busch *et al.,* 2006), also suggested ethnicity or race to be factors associated with HCV RNA negativity in sero-positive blood donors. This assertion could not fully be evaluated during our study.

From all these highlighted arguments, the only feasible explanation for our findings is based on instability in temperatures, coupled with constant freezing and thawing as factors that were responsible for our observations. This explanation is particularly important for blood transfusion practice in Kenya. Blood transfusion is an essential component of quality medical care. However, blood transfusion is a treatment that may also pose potential risks of transfusion related diseases to the patient. Before the introduction of the National Blood Transfusion Services (NBTS), whose aim was to reduce risks of transfusion associated transmission, the risk of transmission of HIV through infected blood was estimated to be 2% based on the fact that HIV prevalence among blood donors was 6.4% (Moore *et al.,* 2001). Although this risk has drastically reduced in HIV (Basavaraju *et al.,* 2010), no similar data show a reduction of this risk transfusion related transmission in HCV.

The findings in our study suggest that even with the introduction of NBTS risk of HCV post transfusion transmission would still be high depending on criteria of collection, blood screening methods and storage of blood bank samples. From our findings, it is clear that the discrepancy seen with archived German and Kenyan samples pointed mainly to the storage methods, hence the complete reduction of RNA below the threshold of detection.

Constant power interruptions, common in Kenya, are a major factor that immensely interferes with refrigeration temperatures. Longer periods of power interruptions will therefore lead to reduction in HCV viremia. Storage at the point of blood donation, distance from the regional blood transfusion centers, coupled with poor infrastructure in the country are a potential for significant reduction in viral load for HCV. This may lead to no detection by the commonly used antibody based assays available for HCV diagnosis. Nucleic Acid based Techniques (NAT) are currently not in use for regular screening or even HCV diagnosis due to high expenses associated with them.

One major limitation of this study was the fact that we were not able to determine the effect of temperature fluctuations on HCV specific antibodies. However, the results realized are suggestive of a significant effect of temperatures on antibody detection.

Just like other studies that have been done on HCV, this study asserts that HCV is an important blood borne viral infection, just like HIV and HBV infections. It concludes that the uncertainty surrounding the true prevalence of HCV in the general population in Kenya is a reason for increased concentration of this infection in blood transfusion services. Achievement in the reduction of HCV post transfusion will mainly depend on determining the true prevalence of the virus in the general population who are the main blood donors in Kenya. Furthermore, it was realized that all the 4 new cases in Kenya did not have any prior knowledge of infection, hence their diagnosis by chance. This may be an indicator on what exists among the general population.

Therefore, this study therefore recommends that a major survey to determine the true prevalence of HCV in the general population in Kenya should be carried out. It further recommends the use of Nucleic Acid based Techniques (NAT) in HCV screening for blood bank samples.

References

Basavaraju, S. V., Mwangi, J., Nyamongo, J., Zeh, C., Kimani, D., Shiraishi, R. W., Madoda, R., Okonji, J.A., Sugut, W., Ongwae, S., Pitman, J. P. and Marum, L. H. (2010). Reduced risk of transfusion-transmitted HIV in Kenya through centrally co-ordinated blood centres, stringent donor selection and effective p24 antigen-HIV antibody screening. *Vox Sanguinis,* **99,** pp 212–219.

Drosten, C., Nippraschk, T., Manegold, C., Meisel, H., Brixner, V., Roth, W. K., Apedjinov, A. and Gunther, S. (2004). Prevalence of Hepatitis B virus DNA in anti-HBCpositive/HBsAg- negative sera correlates with HCV but not HIV serostatus. *Journal of Clinical Virology,* **29,** pp 59-68.

Fasola, F.A. and Otegbayo, I. A. (2002**).** Post-transfusion hepatitis in sickle cell anaemia; retrospective-prospective analysis. *Nigerian Journal of Clinical Practice* **5,** pp 16-19.

Finlayson, M.D.C., Hayes, P.C., Simpson, K.J. (1999). Diseases of the liver and biliary system: Hepatitis. Davidson's principles and practice of medicine eds. Haslett C., Chilvers E.R., Hunter J. *A. A. Churchill Livingstone, London*. pp 706-715.

Ilako, F. M., McLigeyo, S. O., Riyat, M. S., Lule, G. N., Okoth, F. A. and Kaptich, D. (1995). The prevalence of hepatitis C virus antibodies in renal patients, blood donors and patients with chronic liver disease in Kenya. *East African Medical Journal,* **72**, pp 362–364.

Karuru, J. W., Lule, G. N., Joshi, M. and Anzala ,O. (2005). Prevalence of HCV and HCV/HIV co-infection among in-patients at the Kenyatta National Hospital. *East Africa Medical Journal,* **82**(4), pp 170-172.

Klein, H. G. (1995). Allogenic transfusion risk in the surgical patients. *American journal of surgery,* **170,** pp 21-26.

Lesi, O. A., Kehinde, M. O., Anomneze, E. E., Wali, S. S. (2002). Hepatitis C infection and the risk of chronic liver disease in Lagos. Nigerian *Quarterly Journal of Hospital Medicine,* **12**, pp 1-4.

Moore, A., Herrera, G., Nyamongo, J., Lackritz, E., Granade, T., Nahlen, B., Oloo, A., Opondo, G., Muga, R. and Janssen, R., (2001). Estimated risk of HIV transmission by blood transfusion in Kenya. *Lancet* **358** (9282), pp 657-660.

Muasya, T. (2009). Hepatitis B, C and HIV co-infection among a Cohort of Drug Users in Nairobi, Kenya. 5th ISA Conference on HIV Pathogenesis, Treatment and Prevention 19-22 July. (Abstract).

Muasya, T., Lore, W., Yano, K., Yatsuhashi, H., Owiti, F., Fukuda, M., Tamada, Y., Kulundu, J., Tukei, J., Okoth, F. (2008). Prevalence of hepatitis C virus and its genotypes among a cohort of drug users in Kenya. *East African Medical Journal, **85*** (7), pp 318-25.

Talatela, S. P., Matee, I.M. and Munubhi, E. K. (2007). Seroprevalence of hepatitis B and C viral co-infections among children infected with human immunodeficiency virus attending the paediatric HIV care and treatment center at Muhimbili National Hospital in Dar-es-Salaam, Tanzania. *BMC Public Health,* **7**, pp 338.

Tess, B. H., Levin, A., Brubaker, G., Shao, J., Drummond, J. E., Alter, H. J. and O'Brein, T. R. (2000). Seroprevalence of Hepatitis C Virus in the General population of Northwest Tanzania. *American Journal of Tropical Medicine and Hygiene,* **62**(1), pp 138-141.

Turke, P. W., Grant, P. R., Waite, J., Kitchen, A. D., Eglin, R. P., Tedder, R. (2008). Hepatitis C Window-phase infections: closing the window on hepatitis C virus. *Transfusion* **48**, pp 594-600.

UNAIDS (2002). Report on the global AIDS epidemic. Geneva, Joint United Nations program on HIV/AIDS.

WHO (1997). Hepatitis C. Weekly Epidemiological Record, **72**, pp 341-348.

PLATE 1A

1 2 3 4

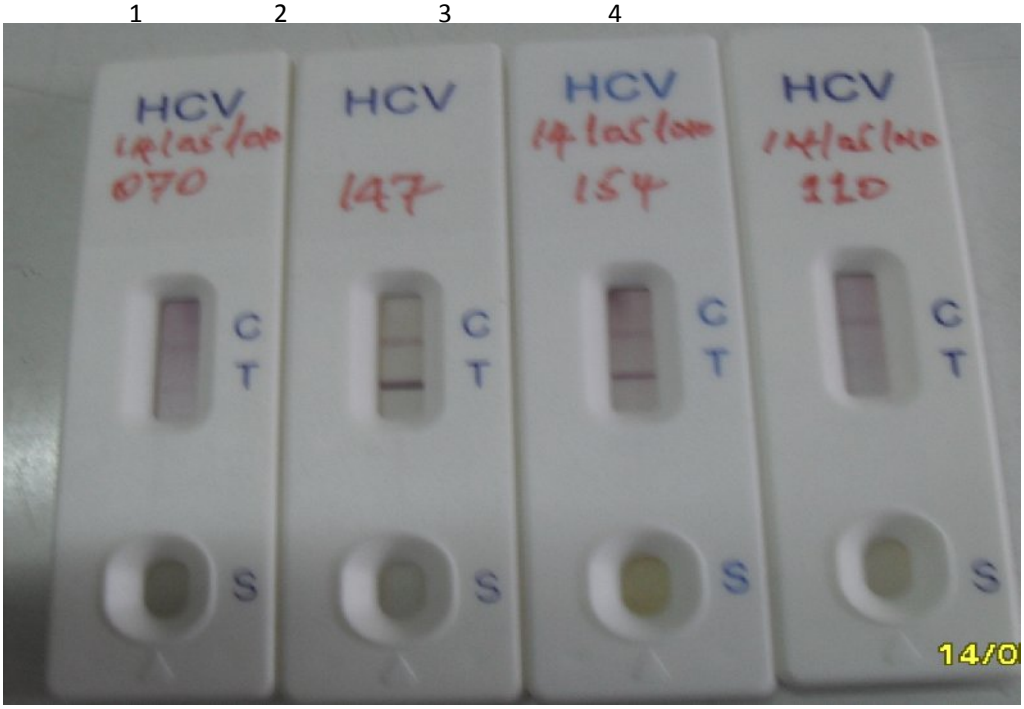


Plate 1a: Clear results shown in kits 2 and 3; kits 1 and 4 show faint bands indicating unclear results

PLATE 1B

Plate 1b: Samples not detected by HCV antibody rapid kit

PLATE 2

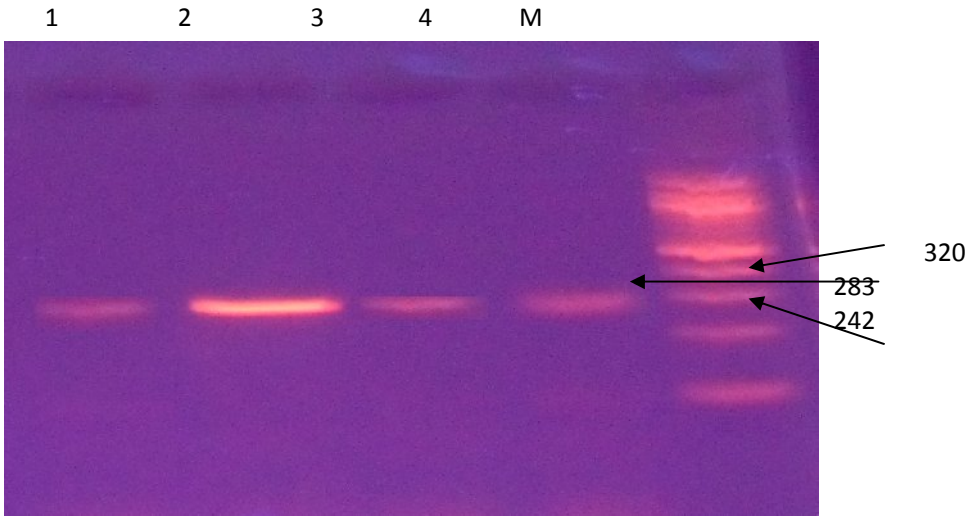


Plate 2: PCR Positive Kenyan samples. M: DNA molecular marker VIII; wells 1 to 4 HCV samples

PLATE 3

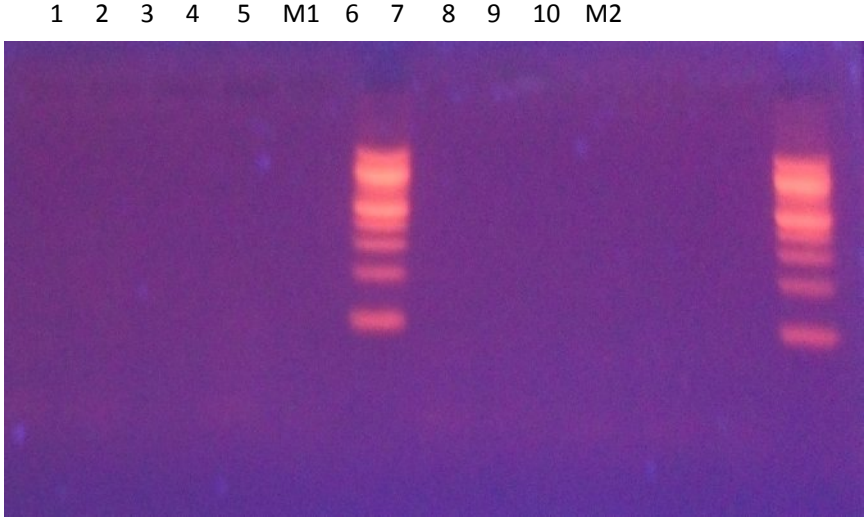


Plate 3: Non detected Kenyan samples by PCR. M1 and M2: DNA molecular weight marker VIII; wells 1 to 10 HCV samples

FIGURE 1

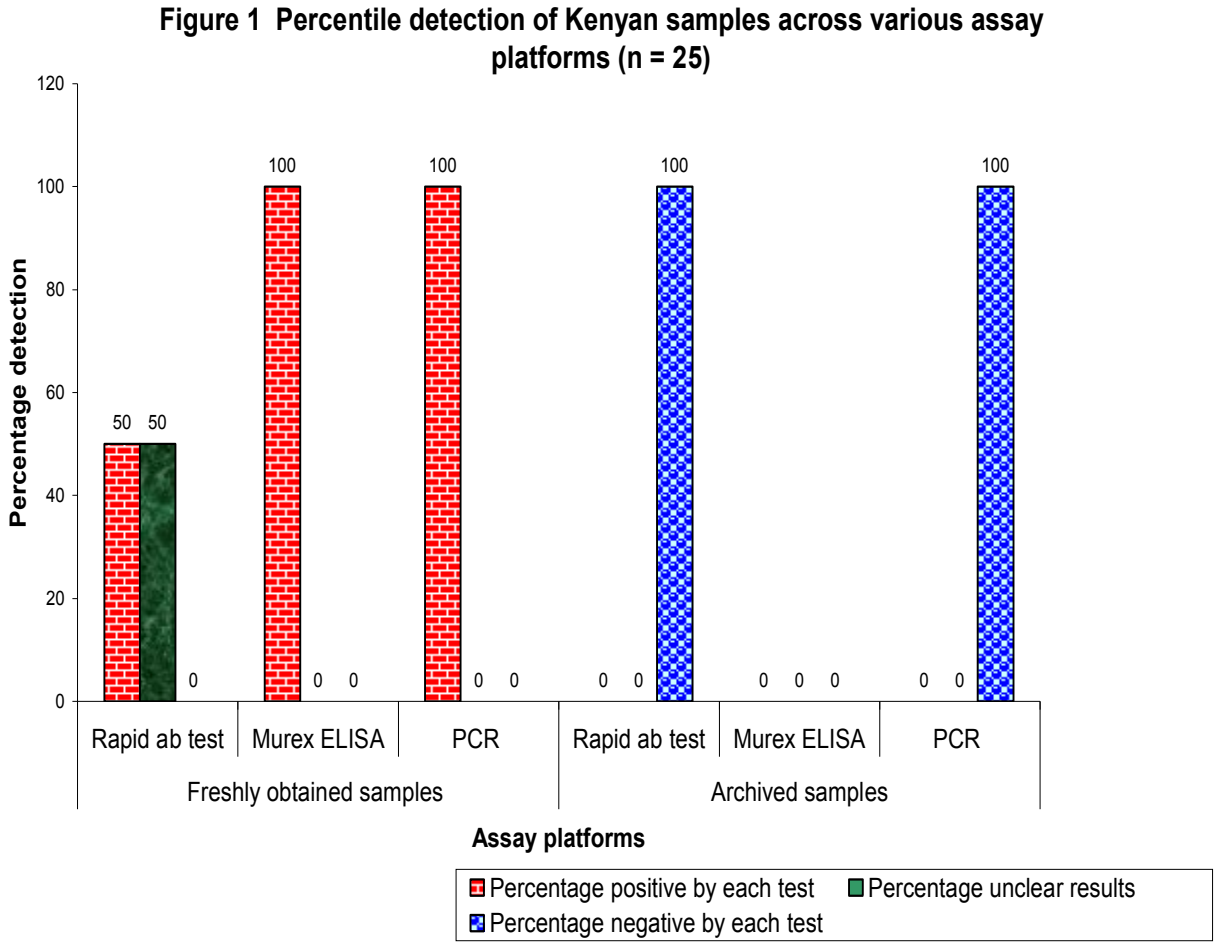


Figure 1: Percentile detection of Kenyan samples across various assay platforms (n = 25)

FIGURE 2

Figure 2: AxSYM ELISA optical density results for PCR negative - Antibody positive samples (n=9).

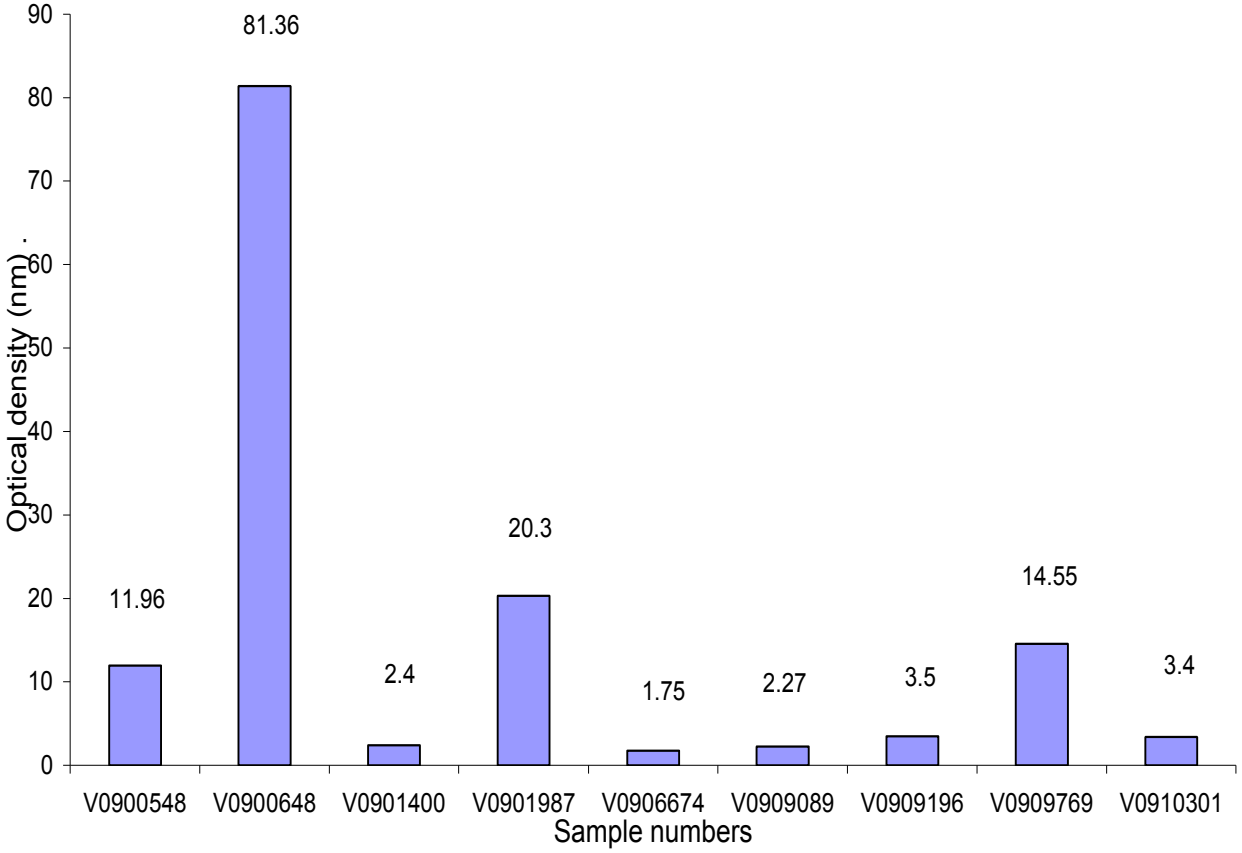


Figure 2: AxSYMELISA optical density results for PCR negative – antibody positive samples (n = 9)

PLATE 4A

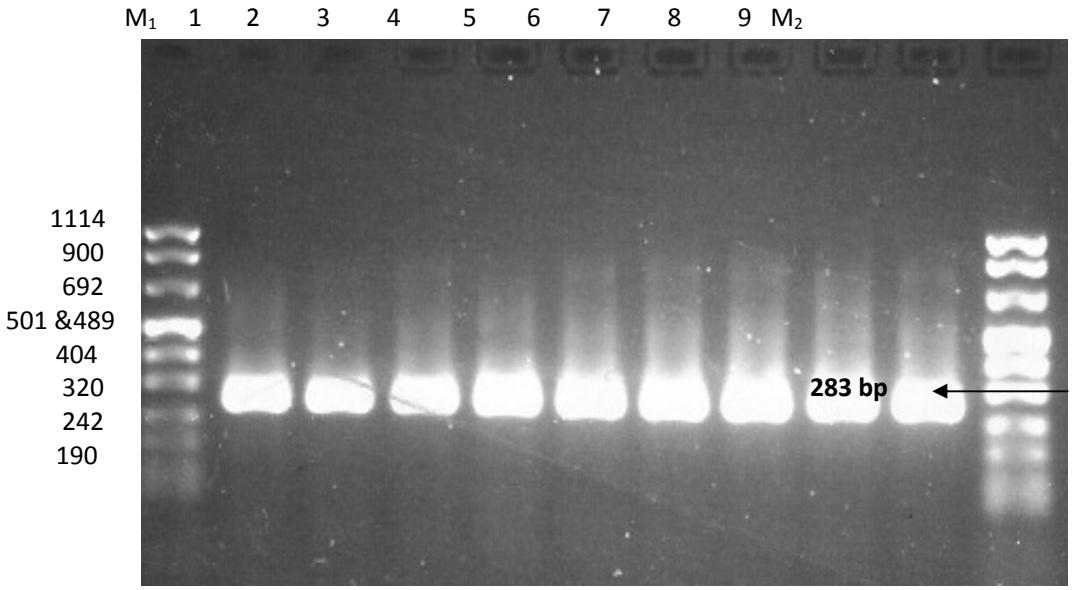


Plate 4a: Nine of the Thirty six archived samples amplified by PCR. M_1 and M_2 - DNA molecular weight marker VIII (0.019 – 1.11 kbp), wells 1 to 9 - bands formed at 283 bp indicating positive results

PLATE 4B

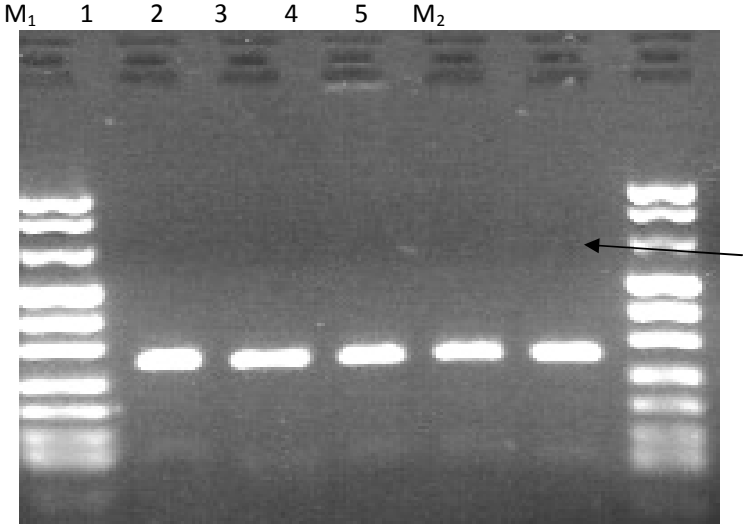


Plate 4b: Five fresh samples amplified by PCR M_1 and M_2 - DNA molecular weight marker VIII (0.019 – 1.11 kbp); wells 1 to 9 – positive bands

FIGURE 3

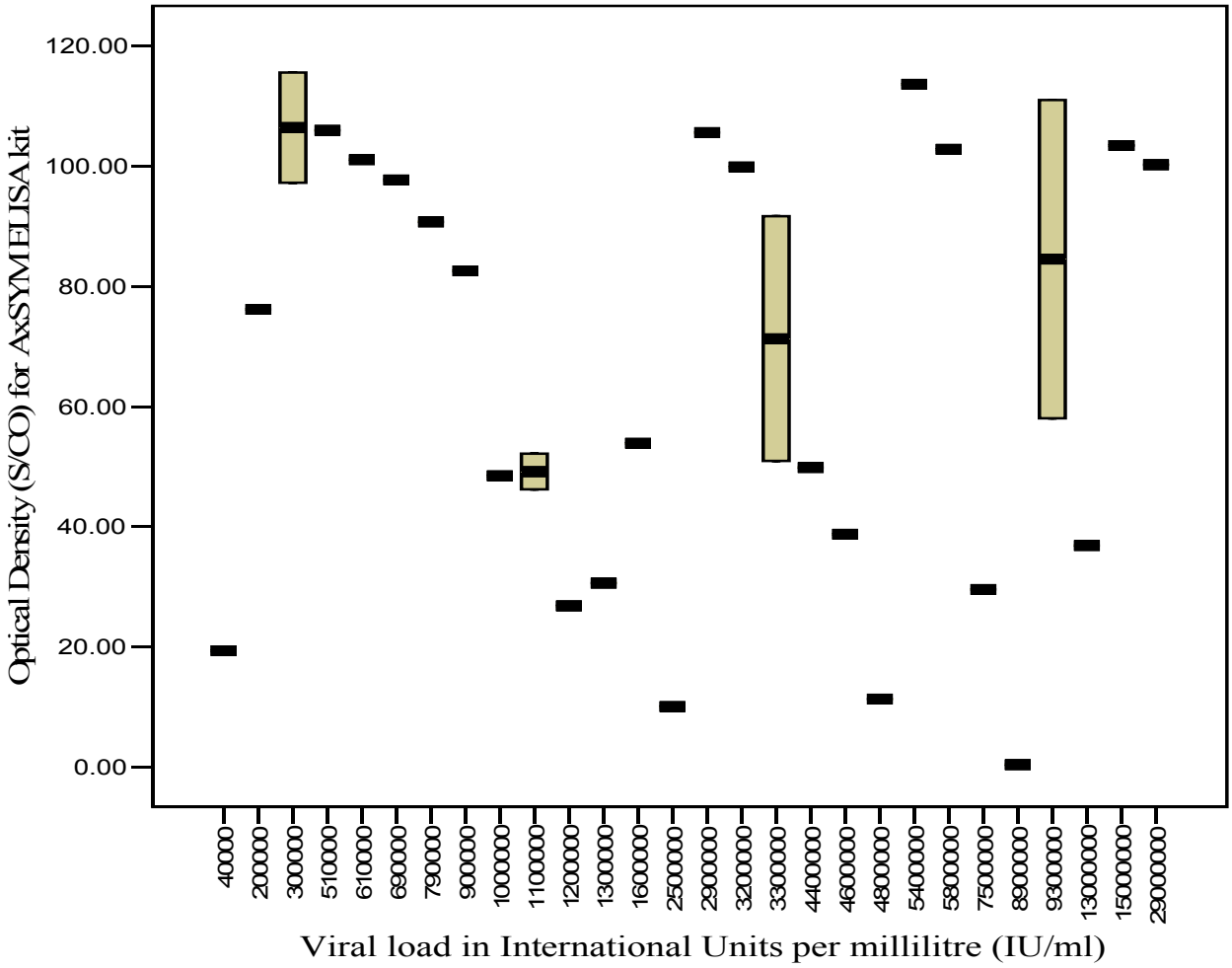


Figure 3: Optical Density versus viral load for some archived and fresh samples

TABLE 1

Table 1: Viral load differences between Frozen and exposed HCV samples (n = 4)

Number	Viral Load (IU/ml)		
	Load before exposure	Load after exposure	Difference in VR
V0836795	$2.1x\ 10^5$	$9.0x\ 10^4$	1.2×10^5
V0836012	$6.0x\ 10^4$	$1.2x\ 10^4$	4.8×10^4
V0832282	$2.0x\ 10^6$	$8.9x\ 10^5$	1.11×10^6
V0831394	$7.1x\ 10^5$	$7.0x\ 10^5$	1.0×10^4

FIGURES 4

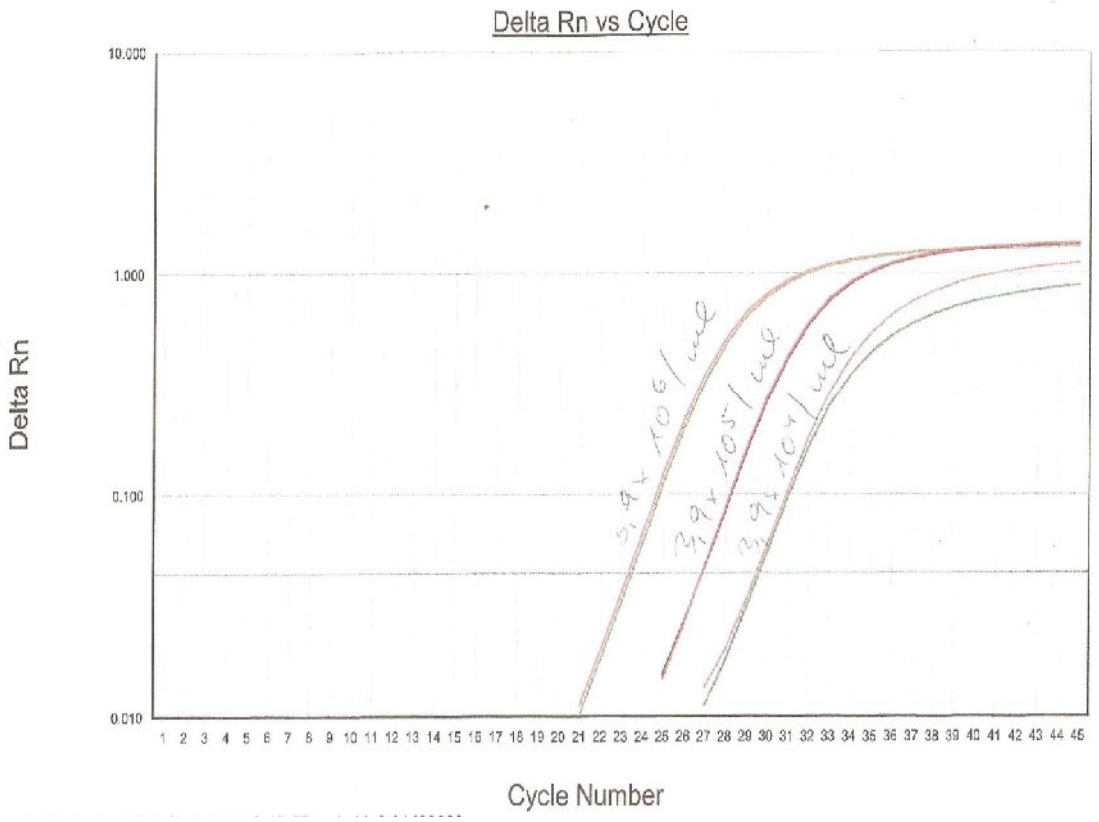
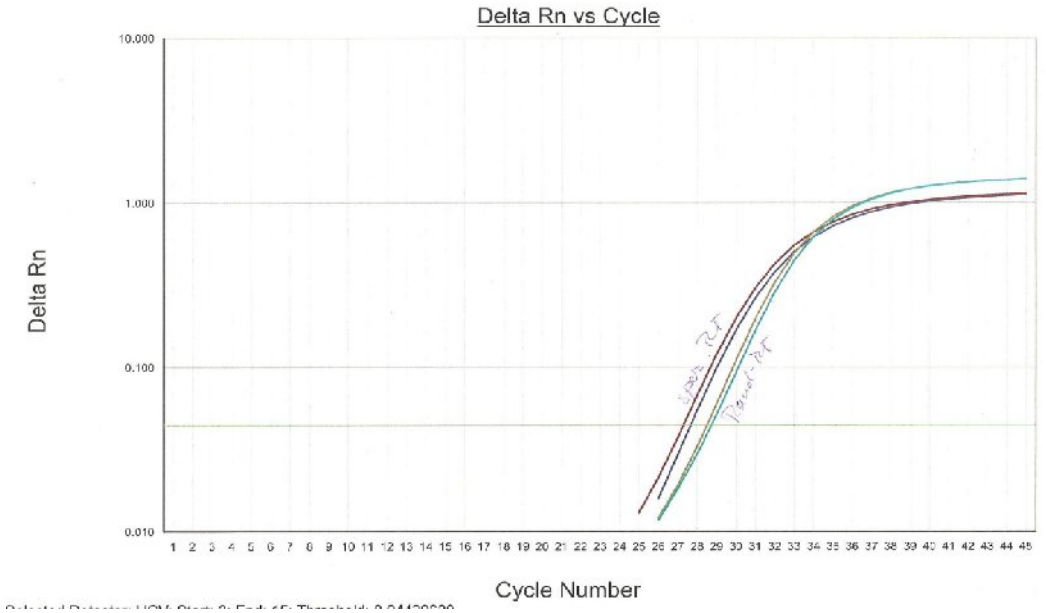


Figure 4a: In-house standards



F*igure 4b: Sample V0836795*

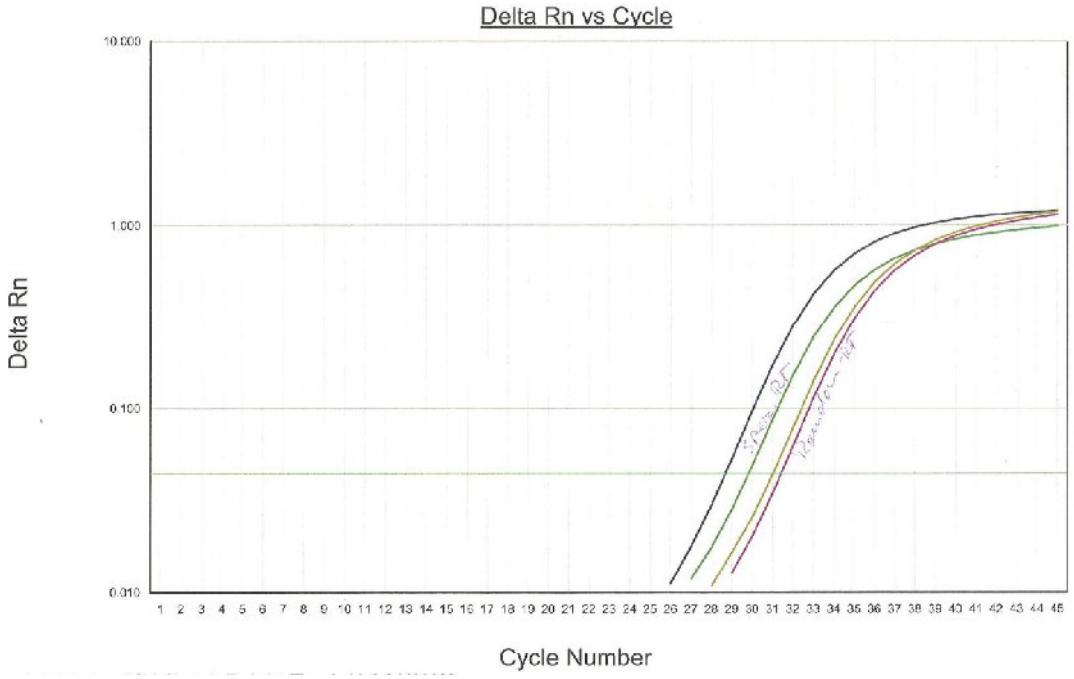


Figure 4c: Sample V0836012

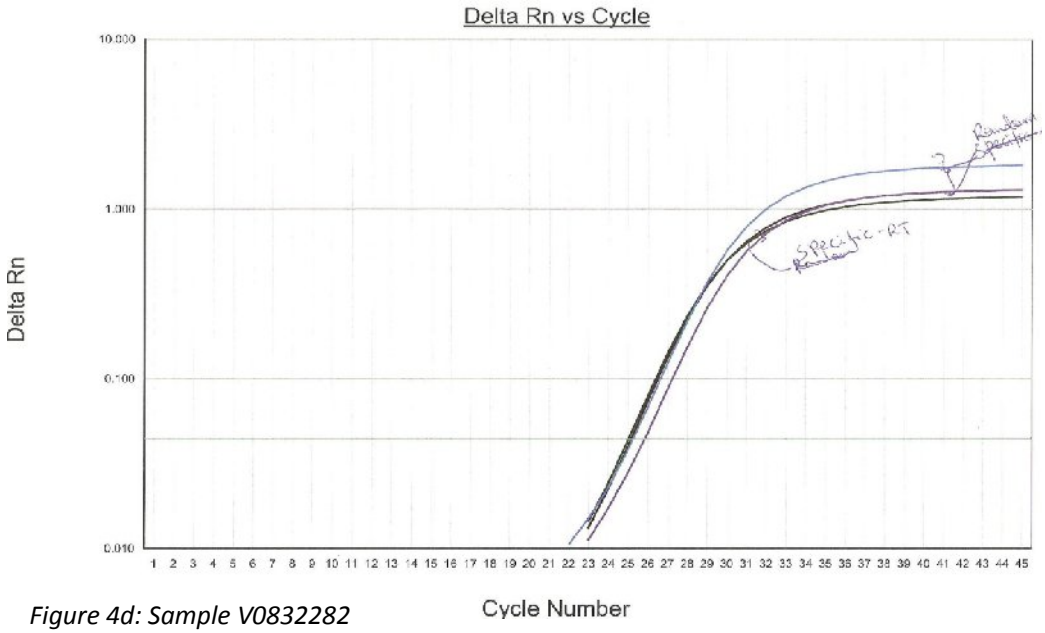


Figure 4d: Sample V0832282

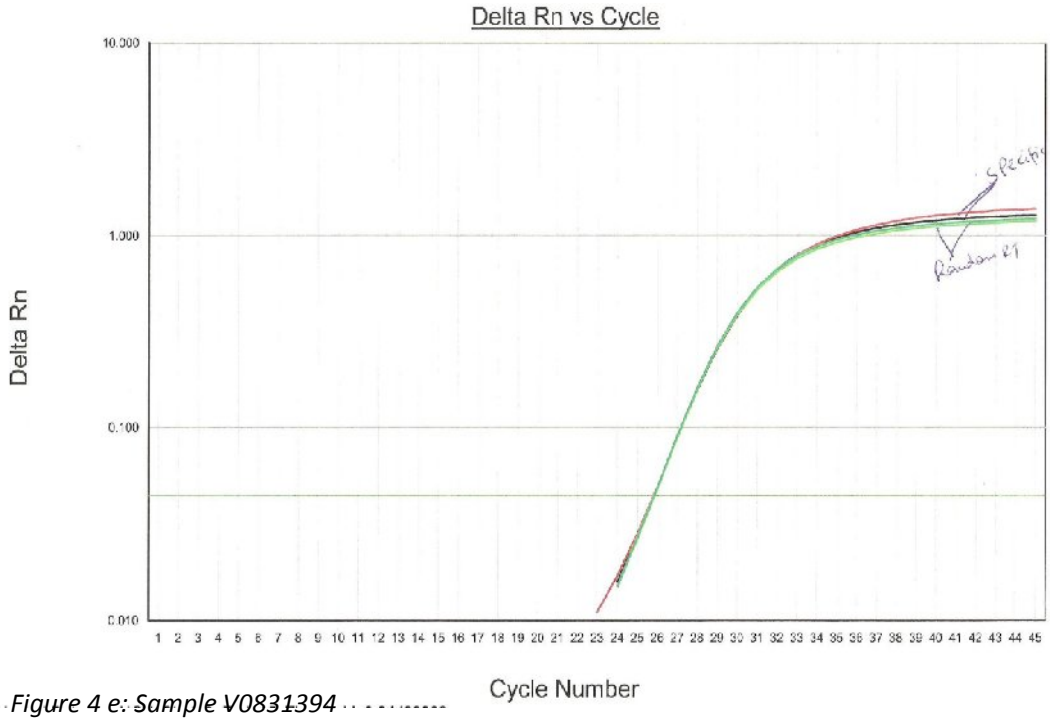


Figure 4 e: Sample V0831394

SUB-THEME III

ENGINEERING TECHNOLOGIES FOR PRODUCTION AND INFRASTRUCTURE

STRESS CONCENTRATION FACTORS IN THICK WALLED CYLINDERS WITH ELLIPTICAL CROSS-BORES

C. A. Adenya[1] and John M. Kihiu[2]
[1,2]Department of Mechanical Engineering, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: adika@eng.jkuat.ac.ke

Abstract
Computer simulations were conducted to determine the elastic stress concentration factors in the vicinity of an elliptical cross-bore in a closed ended thick walled cylinder. The orientation of the elliptical cross-bore with respect to the meridional plane was varied. Various cross-bore to cylinder bore radius ratios and various geometries of the elliptical cross-bore were investigated. A three-dimensional finite element method (FEM) computer programme in FORTRAN code was developed and used to carry out the investigations. The displacement formulation was used. Cylinder geometries of thickness ratios k = 2.0, 2.25 and 2.5 were considered. Cylinder length was taken to be 9 times the wall thickness to avoid the end effects. The maximum stress concentration factor was experienced when the major axis of the elliptical cross-bore lay in the meridional plane. The minimum stress concentration factor was experienced when the major axis of the elliptical cross-bore lay in the transverse plane. For an elliptical cross-bore of cross-sectional area equivalent to that of a circular cross-bore of cross-bore to cylinder bore radius ratio of d = 0.15, the stress concentration factor (SCF) was a constant at 2.1 for angle of rotation (AOR) of 74.5°. For an elliptical cross-bore of cross-sectional area equivalent to that of a circular cross-bore of d = 0.20, the SCF was a constant at 2.1 for AOR = 73°. For an elliptical cross-bore of cross-sectional area equivalent to that of a circular cross-bore of d = 0.25, the SCF was a constant at 2.1 for AOR = 72.5°. When the elliptical cross-bore had its major axis perpendicular to the cylinder axis the SCF was a minimum, i.e., 2.0 and below. The SCF for a circular cross-bore was 3.0. Therefore an elliptical cross-bore offered the lowest SCF when compared to a circular cross-bore. The information on SCF constants obtained will enable quick design of thick walled cylinders with elliptical cross-bore.

Key words: Thick walled cylinder, elliptical cross-bore, stress concentration factor, finite element method

List of Symbols

a	Ellipse semi-major axis (m)
b	Ellipse semi-minor axis (m)
d	Cross-bore to cylinder bore radius ratio
E	Young's modulus (N/m^2)
k	Thickness ratio
K	Stress concentration factor
r	Radial distance from the cylinder axis (m)
r_i	Inside radius of the cylinder (m)
r_o	Outside radius of the cylinder (m)
p	Internal pressure (N/m^2)
σ_a	Axial stress (N/m^2)
σ_c	Hoop stress (N/m^2)
σ_{eff}	Effective stress (N/m^2)
σ_r	Radial stress (N/m^2)
σ_y	Uniaxial yield stress (N/m^2)
v	Poisson's ratio
τ_{max}	Maximum shear stress (N/m^2)
ξ, η, ρ	Natural co-ordinates

Abbreviations

FEM	Finite element method
SCF	Stress concentration factor
AOR	Angle of rotation of the elliptical cross-bore major axis with respect to the meridional plane.

1.0 Introduction

Pressure vessels are leak-proof containers. High pressures, extremes of temperatures and severity of functional performance requirements pose exacting design problems. These have necessitated the studies of modes of failure, methods of stress analysis in pressure vessels, selection of material type and its environmental behaviour. Knowledge of material behaviour is required not only to avoid failures, but also to permit maximum economy of material used (Harvey 1991).

The development of high pressure technology was driven by three primary applications: gun barrel development, the polyethylene process and isostatic pressing (Kendall 2000). Early attempts to improve gun barrel design concentrated on increasing strength of the barrel materials and better projectile loading methods. Polyethylene industry contributed to the understanding of the fatigue and fracture of pressurized cylinders, and the design of pressure seals and high pressure compressors. The process of compacting powders at high pressure and high temperature (hot isostatic pressing), led to the development of a wide variety of hot isostatic pressing vessels operating at pressures up to 345 MPa and temperatures up to 1650 °C.

Developments of space exploration, nuclear and chemical industries have placed new demands on materials suitable for extremes of temperature, impact and fatigue (Harvey 1991). Sometimes these applications also require consideration of other environmental effects such as corrosion, neutron bombardment and hydrogen embrittlement. The chemical industry has greatly increased the importance of correct design for pressure containers (Manning 1957). The combined effects of corrosion, high temperatures, and fluctuating loads have raised the demands beyond those which can be met by straight forward interpretation of ordinary theoretical methods.

Thick pressure vessels are now widely used in nuclear power plants for steam and power generation (Kihiu *et al*., 2003). Other pressure vessel applications might involve as high as 1380 MPa and temperatures of up to 300 °C resulting in the pressure vessel material holding immense potential energy exerted by the working fluid (Kihiu *et al.,* 2003). Such high pressure vessels require proper understanding of the stress concentration levels and distributions for fail-safe design. With pressure vessels holding high potential energy exerted by working fluid, it is important to minimize or even eliminate accidental losses due to poor designs that may result from inadequate understanding of the stresses (Kihiu *et al*., 2004).

Past pressure vessel catastrophic failures arising from the lack of understanding of the stress levels, material properties and fluid/structure environmental interactions, particularly in the past century, were very expensive in terms of losses in materials and human life (Kihiu *et al.*, 2003). These failures were the main impetus for early studies in cylinders of various materials. Later on, the stress distribution in critical sections and metallurgical failure aspects were given more emphasis.

Situations arise when it becomes necessary to provide cross-bores in the pressure vessel wall for a flow circuit, temperature measurement, internal pressure measurement, fluid inlets or outlets, safety valves, and bursting disc (Masu 1989). These openings constitute a major source of weakness. The cross-bores once introduced create regions of high stress concentrations. The severity of the stress concentrations depend on the geometrical configuration of the cross-bore at the junction of the main bore. These stress concentrations not only reduce the pressure carrying capacity of the vessel but also reduce the fatigue life of the vessel (Masu 1989).

Proper understanding of the stress profile in the cylinder and around the cross-bore is essential in estimating the maximum permissible operating pressure. A clear understanding of the stress profile would help in better design (Hameed *et al.*, 2004). For high pressure applications, a clear understanding of the state of stress in a vessel with side bores is needed because fatigue life is very

critical and limitations of strength and ductility in commercial pressure vessel materials prevent high factors of safety (Faupel and Harris 1957).

A theoretical and experimental study has been done on stress concentration induced in a cylinder under internal pressure by the presence of circular side holes and elliptical side holes with major axis of the ellipse perpendicular to the meridional axis of the cylinder (Faupel and Harris 1957). The theoretical study was based on analyses for holes in infinite elastic plates subjected to axial or biaxial stresses. The experimental analysis was done using both strain gauges and photo-elasticity method. Hoop stress concentration factor for closed-ended cylinder with a small circular cross-bore was found to be 2.5.

Research has been done to establish and quantify the influence of cross-bore entry geometry on the elastic and elastic-plastic stresses and their distribution in thick walled cylinders under internal pressure (Kihiu 2002). The analysis was done by computer simulation using 3-dimensional FEM procedures. Pressure vessel material was high strength SA-372 steel. Model cylinders had varying thickness ratio, varying cross-bore diameters, and cross-bores with varying cross-bore to main bore entry geometry. Plain cross-bores, radiused cross-bores and chamfered cross-bores were considered. For plain cross-bored cylinders, for thickness ratio between 1.75 and 3, the stress concentration factor was determined as a constant value of 2.753 for cross-bore to main bore radius ratio of 0.2. When the cross-bore to main bore radius ratio was less than 0.2, the stress concentration factor increased with increasing thickness ratio, whereas, when the cross-bore to main bore radius ratio was more than 0.2, the stress concentration factor increased with decrease in thickness ratio. For radiused entry cross-bored cylinder the stress concentration factors and stress gradients were lower than those of an equivalent plain cross-bored cylinder. Maximum hoop stress was located near the upper end of the entry radius in the meridional plane. Stress concentration factor reduced with increase in cross-bore entry radius. For chamfered entry cross-bore, varying the chamfer angles may result in minimum stress concentration factor lower than those in an equivalent plain cross-bored cylinder, but higher than those in an equivalent radiused entry cross-bored cylinder.

A 3-dimensional FEM computer program was developed to establish the stress distribution and stress concentration factors in thick walled cylinders with plain cross-bores under internal pressure (Kihiu et al. 2003). The displacement formulation and eight nodded brick isoparametric elements were used. The frontal solution technique was used. For a thickness ratio of less than 1.75, cross-bore to main bore radius ratio was a found to be a geometric constant equal to 0.11 where the stress concentration factor was 2.67. For a thickness ratio of more than 1.75, cross-bore to main bore radius ratio was found to be a geometric constant equal to 0.2 where the stress concentration factor was 2.734.

Limited study has been done on of the elastic stress profiles and the SCF in a thick walled cylinder with a radial elliptical cross-bore whose orientation with respect to the cylinder axis is varying. To avoid the enormous losses of property and human life that may occur due to a high pressure vessel failure, it is imperative to know the stress concentration factors and the stress profiles that arise in the vicinity of the elliptical cross-bore when the cylinder is loaded with an internal pressure while in service

1.1 Theoretical Background

The shape of an ellipse with centre located at (0, 0) is given by (Wikipedia):

$$(x/a)^2 + (y/b)^2 = 1 \quad \text{.....(1)}$$

The area of an ellipse is given by (Wikipedia):

$A_{ellipse} = \pi ab$ .....(2)

The eccentricity *e* of an ellipse is given by (Wikipedia):

$$e = \sqrt{1-(b/a)^2} \quad \text{.....(3)}$$

Using von Mises yield criterion, the effective stress is given by (Dowling 1993):

$$\sigma_{eff} = \sqrt{\left((\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2\right)/2} \quad \text{.....(4)}$$

SCF can be defined as the ratio of the peak stress in the body to some other stress taken as a reference (Pilkey and Pilkey 2008). The hoop stress concentration factor is the ratio of the maximum hoop stress at the intersection of the cross-bore and the cylinder bore to the Lame's hoop stress at the bore of a vessel without a cross-bore (Dixon et al. 2004):

$$K_t = \sigma_{\max-hoop} / \sigma_{lame's-hoop} \quad \text{.....(5)}$$

If an elliptical hole is made in a plate with its major axis perpendicular to the direction of the uniform tensile stress the maximum stress will be at the end of the major axis. The theoretical stress concentration factor is given by (Timoshenko 1958).

$$K_t = (1+2(a/b)) \quad \text{.....(6)}$$

For three-dimensional case, the elastic stress-strain matrix for isotropic material is given by (Bathe 1996):

$$C = \frac{E(1-\nu)}{(1+\nu)(1-2\nu)} \begin{bmatrix} 1 & \frac{\nu}{(1-\nu)} & \frac{\nu}{(1-\nu)} & 0 & 0 & 0 \\ \frac{\nu}{(1-\nu)} & 1 & \frac{\nu}{(1-\nu)} & 0 & 0 & 0 \\ \frac{\nu}{(1-\nu)} & \frac{\nu}{(1-\nu)} & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1-2\nu}{2(1-\nu)} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1-2\nu}{2(1-\nu)} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1-2\nu}{2(1-\nu)} \end{bmatrix} \quad \text{.....(7)}$$

2.0 Methodology

The pressure vessel material considered was a high strength SA 372 steel of yield stress 450 MPa, Young's modulus of 209 GPa and Poisson's ratio of 0.29 (Mraz and Nisbett 1980). Due to symmetry, the plain cylinder was represented by a quarter of the structure (Kihiu 2002),

Figure ***1***. Half of the structure was used to represent the cylinder with an elliptical cross-bore,

Figure ***2***. This greatly reduced the computer memory requirements and computer run time.

For comparison purposes, elliptical cross-bores of cross-sectional area equivalent to that of a given circular cross-bore were studied. The cross-bore was initially circular. Its dimensions were then varied to form an elliptical cross-bore of the same cross-sectional area. The cross-bore to cylinder bore radius ratio refers to that of the circular cross-bore.

The elliptical cross-bore major axis initially lay in the meridional cross-section. The AOR was then measured anticlockwise from the cylinder axis to define the new orientation of the major axis of the elliptical cross-bore with respect to the cylinder axis.

The procedure for the finite element displacement formulation included the following (Zienkiewicz 1971; Segerlind 1984; Reddy 1993; Zienkiewicz and Taylor 1994; Krishnamoorthy 1995):

(i) Discretization of the structure into eight noded brick isoparametric elements,

(ii) Figure ***1*** and

(iii) Figure ***2***. This involved locating the nodes, numbering and specifying their coordinate values, numbering the element and determining the connectivity matrix.

(iv) Determination of element properties from material and loading data. This involved specifying the approximation equation for force-displacement relationships. Equations were written in terms of the unknown nodal displacements.

(v) Determination of the stiffness matrix and the corresponding nodal loads for each element. Serendipity family element shape functions were used for their simplicity. The shape function defining the geometry and variation of displacement for the eight-noded (brick) isoparametric element is given by (Krishnamoorthy 1995):

$$N_i = (1 + \xi\xi_i)(1 + \eta\eta_i)(1 + \rho\rho_i)/8 \quad i = 1, 2, , 8 \quad \text{.....(8)}$$

Where ξ, η, ρ are natural coordinates of the Gaussian sampling points and ξ_i, η_i, ρ_i are the values of natural coordinates for node *i*.

Numerical integration procedure was used for evaluating the stiffness matrix using Gauss quadrature. The 2x2x2 scheme was adequate for the 8-noded linear element (Krishnamoorthy 1995).

(vi) Assembly of the element stiffness matrices and load vectors to generate the global stiffness matrix and the global load vector respectively.

(vii) Application of boundary conditions on the assembled global stiffness matrix and global load vector.

(viii) Solving the resulting system of equations to determine the nodal displacements. Frontal solution (Yeo 1973) technique was used to solve the linear equations that resulted from the finite element method formulation. This was to overcome the computer memory limitation that occurs when dealing with a large number of elements.

(ix) Evaluation of strains and stresses for each element using the nodal displacements and the element properties. The stress in individual element was obtained at the Gauss points and then projected to the element nodes. The nodal stresses obtained by linear least-square extrapolation were then averaged to obtain local smoothing of the stress distribution (Chen *et al*. 1996).

3.0 Discussion

The results of a plain cylinder are presented as indication of the validity, accuracy and, therefore, reliability of the elastic finite element method analysis used for this research.

3.1 Plain Cylinder

3.1.1 Displacements

Figure ***5*** compares the radial displacements obtained by the finite element method to those obtained analytically along edge AB or CD for the plain cylinder. The numerical displacements obtained by the finite element method were very close to the analytical values. The maximum error in determining the displacements was 0.40 %. The average error for all points investigated was 0.39 %. This therefore shows the reliability of the FEM program developed

3.1.2 Stresses

Figure ***6*** shows the dimensionless elastic stress distribution across a plain cylinder wall. It compares the elastic hoop, radial and axial stresses obtained by the analytical and the finite element method. The stress profiles obtained from the finite element program agreed very well with the analytical stress profiles.

Nodes inside the material gave very accurate stress values. They were very close to the analytical values. Maximum stress errors were experienced at the cylinder's outside surfaces. These can be accommodated as the critical points are at the cylinder bore. Hoop stress error at the inside surface was 0.53 %. Hoop stress error at the outside surface was 3.87 %. For nodes inside the material, the hoop stress errors varied between 0.31 % and 0.48 %. Radial stress error at the inside surface was 4.17 %. At the outside surface the radial stress varied slightly from the theoretical zero value. For nodes inside the material, the radial stress errors varied from 0.74 % to 2.02 %. Axial stress error at the inside surface was 4.32 %. Axial stress error at the outside surface was 6.96 %. For nodes inside the material, the axial stress errors varied from 0.03 % to 0.18 %. The finite element method showed very high accuracy for nodes inside the material. Therefore, the results of the FEM are admissible.

3.2 Meridional Stresses

3.2.1 Circular Cross-bore

Figure ***7*** shows the dimensionless elastic meridional stresses for a cylinder with a circular cross-bore. These profiles can be explained by considering the cross-bore and the cylinder bore as two interacting cylinders, each with its coordinate system and loaded by the same internal pressure. Take the cross-bore as a hole in an irregular block.

Approaching the cross-bore, the hoop stress increased tremendously. This occurred because in the meridional plane, the hoop stresses due to the two cylinders superimpose positively. From N to K the magnitude of the hoop stress reduces since the hoop stress due to the cylinder bore loading reduces.

Approaching the cross-bore, the radial stress reduces sharply and then reduces very slowly. The interaction of the cylinder axial stress and the cross-bore radial stress in the meridional plane is negative. The magnitude of the tensile axial stress is reduced by the compressive radial stress arising due to the loading of the cross-bore.

Along NK the radial stresses due to the loading of the cylinder bore are experienced. There is no interaction with any other stresses arising from the loading of the cross-bore. Therefore the profile obtained is that for radial stress in an internally loaded cylinder. σ_y

3.3 Elliptical Cross-bore Parallel to Cylinder Axis

Figure ***8*** shows the dimensionless elastic meridional stresses for a cylinder with an elliptical cross-bore parallel to the cylinder axis. The ratio of *b/a* = 0.5 was considered. Comparing these stresses to those of the circular cross-bore of same area the maximum hoop stress increased by 70 %. The hoop stress at the intersection of cross-bore and cylinder outside surface increased by 113 %. The maximum axial stress (compressive) reduced by half. The maximum radial stress increased by 540 %.

3.4 Elliptical Cross-bore Perpendicular to Cylinder Axis

Figure ***9*** shows the dimensionless elastic meridional stresses for a cylinder with an elliptical cross-bore perpendicular to the cylinder axis.

Comparing these stresses with those for an elliptical cross-bore with major axis parallel to the cylinder axis, the maximum hoop stress reduced by 67 %. The hoop stress at point K reduced by 81 %. The maximum compressive axial stress at point K increased by 130 %. The radial stress at point K reduced by 84 % and changed from tensile to compressive. Comparing these stresses with those for a circular cross-bore, the maximum hoop stress reduced by 43 %. Hoop stress at point K reduced by 60 %. The maximum compressive axial stress increased by 15 %. The radial stress at point K increased by 17 %.

3.5 Transverse Stresses

3.5.1 Circular Cross-bore

Figure ***10*** shows the dimensionless elastic transverse stresses for a cylinder with a circular cross-bore along the surface RSH. These stress profiles are explained by considering the cross-bore and the cylinder bore as two interacting cylinders, each with its coordinate system and loaded by the same internal pressure. Take the cross-bore as a hole in an irregular block.

Approaching the cross-bore, the hoop stress dropped sharply from tensile to compressive. This is due to its interaction with the compressive radial stresses arising from the loading of the cross-bore. The compressive radial stresses counter the tensile hoop stresses arising from the cylinder bore loading.

Axial stress increased when approaching the cross-bore. At the cross-bore these stresses interact with the hoop stresses arising from the cross-bore loading. Since both stresses are tensile, they positively add up.

Radial stress does not interact directly with the other stresses arising due to the cross-bore loading. Therefore it takes the same profile of the radial stresses in an internally loaded cylinder.

3.5.2 Elliptical Cross-bore Parallel to Cylinder Axis

Figure ***11*** shows the dimensionless elastic meridional stresses for a cylinder with an elliptical cross-bore parallel to the cylinder axis.

Comparing these stresses with those for a circular cross-bore, the hoop stress has varied very slightly. The compressive hoop stress along SH increased by between 16 % and 19 %. The axial stress at point S reduced by 98 % and became compressive. The axial stress along the cross-bore was largely compressive. The radial stress changed very slightly. Along the cross-bore immediately after point S the compressive radial stress increased by 17 %.

3.5.3 Elliptical Cross-bore Perpendicular to Cylinder Axis

Figure ***12*** shows the dimensionless elastic meridional stresses for a cylinder with an elliptical cross-bore perpendicular to the cylinder axis. Comparing these stresses with those for a circular cross-bore, the maximum compressive hoop stress reduced by 33 %. The axial stresses increased throughout the cross-bore length. At point H axial stress increased by 167 %. The radial stress at point H increased by 320 % and changed from compressive to tensile.

Comparing these stresses with those for an elliptical cross-bore with major axis parallel to the cylinder axis, the maximum compressive hoop stress reduced by 42 %. The axial stress at point H increased by 2833 %. The radial stress profile gave a smooth curve along the cross-bore. The radial stress at point H increased by 75 % and changed from compressive to tensile

3.6 Stress Concentration Factors for Elliptical Cross-Bore

Effective stress gives a complete representation of the state of stress at a point. Due to the shape of the elliptical cross-bore, the effective stress would give better representation of the stresses around the cross-bore rather the hoop stress alone. The effective stress was therefore used to determine the stress concentration factors.

For each thickness ratio, elliptical cross-bores with cross-sectional area equivalent to circular cross-bores of cross-bore to cylinder bore radius ratios of 0.15, 0.20, and 0.25 were investigated. The ratios of b/a equal to 0.1, 0.3, 0.5, and 0.7 were considered.

Figure ***13***,

Figure ***14***, and Figure 15 show the variation of the SCF with the orientation of an elliptical cross-bore which had the same cross-sectional area as a circular cross-bore of cross-bore to cylinder bore ratio of 0.15, 0.20 and 0.25 respectively.

As AOR increased from 0° to 90°, the SCF reduced from a maximum to a minimum value. Therefore, an elliptical cross bore oriented perpendicular the cylinder axis gave the minimum SCF for any geometry considered. This can be explained by considering the orientation of the elliptical cross-bore with respect to the directions of the stresses.

When the angle of rotation was zero, the cross-bore major axis was aligned perpendicular to the direction of the hoop stresses. From equation (6), the maximum stress and therefore the maximum SCF will be at the end of the major axis, i.e., the meridional plane. When the cross-bore is rotated,

the orientation of the cross-bore major axis with hoop stresses changed until they were parallel. From equation (6) the factor *a/b* becomes a less than 1.0. Therefore the SCF reduces.

When the cross-bore major axis is perpendicular to the cylinder axis, it also aligned perpendicular to the axial stresses. The axial stresses are of great magnitudes. These axial stresses play a big role in the SCF. The axial stresses are a maximum in the transverse cross-section at the intersection of the cross-bore and cylinder outside surface. For any given thickness ratio, when *b/a* = 0.1, the SCF was a minimum. When *b/a* was increased to 0.3, the SCF increased to the maximum. When *b/a* was changed to 0.5, the SCF reduced. When *b/a* = 0.7, the SCF reduced further but did not fall below those obtained for *b/a* = 0.1.

Thus the size and orientation of geometric discontinuities with respect to applied stress play a large role in determining the stress concentration. Stress concentration factor is a function of the type of discontinuity (hole, fillet, or groove), the geometry of the discontinuity, and the type of loading being experienced (Hamrock *et al*., 2004).

When the thickness ratio was increased from 2.00 to 2.25 to 2.50, the SCF decreased. The magnitude of the difference declined as the angle of rotation changed from 0° to 90°. This trend continued as the cross-bore was rotated, until when nearing angle 90° when the reverse occurred for some cases of cross-bore to cylinder bore radius ratios of 0.2 and 0.25.

Considering

Figure ***13***, thickness ratio *d* = 0.15, when *b/a* = 0.1, as the AOR changed from 0° to 90°, SCF decreased from 2.7 to 1.4. These values of SCF are below that of a circular cross-bore of 3.0. When *b/a* = 0.3, as the AOR changed from 0° to 90°, SCF decreased from 4.2 to 1.8. At AOR of above 45°, the SCF was below 3.0. When *b/a* = 0.5, as the AOR changed from 0° to 90°, SCF decreased from 3.7 to 1.6. At AOR of above 45°, the SCF was below 3.0. When *b/a* = 0.7, as the AOR changed from 0° to 90°, SCF decreased from 3.2 to 2.0. At AOR of above 15°, the SCF was below 3.0. This trend was replicated for the other thickness ratios investigated.

From

Figure ***13***, for cylinder of thickness ratios of 2.0, 2.25, and 2.5, and an elliptical cross-bore, whose cross-sectional area is equivalent to a circular cross-bore of cross-bore to cylinder bore radius ratio of 0.15, the SCF was a constant at 2.1 when the cross-bore major axis was rotated 74.5°, with respect to the cylinder axis, for values of *b/a* of 0.3, 0.5, and 0.7.

From

Figure ***14***, for cylinder of thickness ratios of 2.0, 2.25, and 2.5, and an elliptical cross-bore, whose cross-sectional area is equivalent to a circular cross-bore of cross-bore to cylinder bore radius ratio of 0.20, the SCF was a constant at 2.1 when the cross-bore major axis was rotated 73°, with respect to the cylinder axis, for values of *b/a* of 0.3, 0.5, and 0.7. For *b/a* of 0.1, the SCF was a constant at 1.45 when the cross-bore major axis was rotated 66° with respect to the cylinder axis.

From Figure 15, for cylinder of thickness ratios of 2.0, 2.25, and 2.5, and an elliptical cross-bore, whose cross-sectional area is equivalent to a circular cross-bore of cross-bore to cylinder bore radius ratio of 0.25, the SCF was a constant at 2.1 when the cross-bore major axis was rotated 72.5°, with respect to the cylinder axis, for values of *b/a* of 0.3, 0.5, and 0.7. For *b/a* of 0.1 the SCF was a constant at 1.55 when the cross-bore major axis was rotated 66° with respect to the cylinder axis.

4.0 Conclusion

This study involved the development a finite element method computer program to analyze elastic stresses in a thick walled cylinder with an elliptical cross-bore. Investigations were carried out to determine the stress profiles and stress concentration factors for various cross-bore geometries and for various cross-bore orientations with respect to the cylinder axis. The stress profiles and the stress concentration factors indicate the critical points to be considered when designing a cylinder with an elliptical cross-bore.

The results obtained from this research give details on the stress profiles and SCF that arise for a radial elliptical cross-bore at any orientation with respect to the cylinder axis. These results form a good basis for re-evaluating existing data for design of cylinders with elliptical cross-bores. The program developed can be modified further, commercialized and used to collect more data for design.

The data obtained in this research will be used in guiding the design of pressure vessels with elliptical cross-bores. The data obtained on SCF constants should be used to enable quick design of thick walled cylinders with elliptical cross-bore.

From this investigation, the elliptical cross-bore is advantageous over the circular cross-bore, of the same cross sectional area. When the elliptical cross-bore had its major axis oriented perpendicular to the cylinder axis the SCF obtained was a minimum, that is, 2.0 and below. This is commendable compared to the average SCF for a circular cross-bore of 3.0. Thickness ratio of d = 0.20 and b/a = 0.1 resulted in the least values of SCF of between 2.5 and 1.3. For the thickness ratios investigated with b/a = 0.3 and b/a = 0.5, the SCF was below 3.0 for AOR above 45°, where as for b/a = 0.7, the SCF was below 3.0 for AOR above 20°.

Acknowledgement

We are grateful to the management of Jomo Kenyatta University of Agriculture and Technology for enabling us carry out this research work.

References

Bathe, K. J. (1996). Finite Element Procedures, Prentice Hall, Englewood Cliffs, New Jersey.

Chen, D. J., Shah, D. K. and Chan, W. S. (1996). "Using Stress Smoothing for Interlaminar Stress Distribution in Finite Element Analysis of Composite Laminates." *Key Engineering Material,* **121-122**, pp 203-224.

Dixon, R. D., Peters, D. T. and Keltjens, J. G. M. (2004). "Stress Concentration Factors of Cross-Bores in Thick Walled Cylinders and Blocks." *Transactions of ASME, Journal of Pressure Vessel Technology,* **126**, pp 184 - 187.

Dowling, N. E. (1993). Mechanical Behaviour of Materials - Engineering Methods for Deformation, Fracture and Fatigue, Prentice Hall International Editions.

Faupel, J. H. and Harris, D. B. (1957). "Stress Concentration in Heavy-Walled Cylindrical Pressure Vessels." *Industrial and Engineering Chemistry,* **49**(12), pp 1979 - 1986.

Hameed, A., Brown, R. D. and Hetherington, J. (2004). "A Study of the Residual Stress Distribution in an Autofrettaged, Thick-Walled Cylinder with Cross-Bore." *Journal of Pressure Vessel Technology,* **126**, pp 497 - 503.

Hamrock, B. J., Schmid, S. R. and Jacobson, B. O. (2004). Fundamentals of Machine Elements, McGraw-Hill Professional.

Harvey, J. F. (1991). Theory and Design of Pressure Vessels, Chapman & Hall.

Kendall, D. P. (2000). "A Short History of High Pressure Technology From Bridgham to Division 3." *Journal of Pressure Vessel Technology,* **122**, pp 229 - 233.

Kihiu, J. M. (2002). Numerical Stress Characterization in Cross-Bored Thick walled Cylinders Under Internal Pressure, The University of Nairobi.

Kihiu, J. M., Mutuli, S. M. and Rading, G. O. (2003). "Stress Characterization of Autofrettaged Thick Walled Cylinders." *International Journal of Mechanical Engineering Education,* **31**(4), pp 370 - 389.

Kihiu, J. M., Rading, G. O. and Mutuli, S. M. (2003). "Geometric Constants in Plain Cross Bore Cylinders." *Journal of Pressure Vessel Technology,* **125**, pp 446 - 453.

Kihiu, J. M., Rading, G. O. and Mutuli, S. M. (2004). "Overstraining of Flush Plain Cross-Bored Cylinders." Proceedings of Institution of Mechanical Engineers, Part C: *Journal of Mechanical Engineering Science* **218**, pp 143-153.

Krishnamoorthy, C. S. (1995). Finite Element Analysis - Theory and Programming, Tata McGraw-Hill Publishing Company Limited, New Delhi.

Manning, W. R. D. (1957). "Strength of Cylinders." *Industrial and Engineering Chemistry,* **49**(12), pp 1969 - 1978.

Masu, L. M. (1989). The Effect of Cross Bore Geometry on the Strength of Pressure Vessels, The University of Leeds.

Mraz, G. J. and Nisbett, E. G. (1980). "Design, Manufacture and Safety Aspects of Forged Vessels for High-Pressure Services." Transactions of ASME, *Journal of Pressure Vessel Technology,* **102**, pp 98 - 106.

Pilkey, W. D. and Pilkey, D. F. (2008). Peterson's Stress Concentration Factors, John Wiley and Sons.

Reddy, J. N. (1993). An Introduction to the Finite Element Method, McGraw Hill International.

Segerlind, L. J. (1984). Applied Finite Element Analysis, John Wiley and Sons, New York.

Timoshenko, S. P. (1958). Strength of Materials Part II: Advanced Theory and Problems, Krieger.

Wikipedia http://en.wikipedia.org/wiki/Ellipse.

Yeo, M. F. (1973). "A More Efficient Front Solution: Allocating Assembly Locations by Longevity Considerations." *International Journal for Numerical Methods in Engineering,* **7**, pp 570 - 573.

Zienkiewicz, O. C. (1971). The Finite Element Method in Engineering Science, McGraw-Hill, London.

Zienkiewicz, O. C. and Taylor, R. L. (1994). The Finite Element Method, McGraw-Hill Book Company, London.

Figures

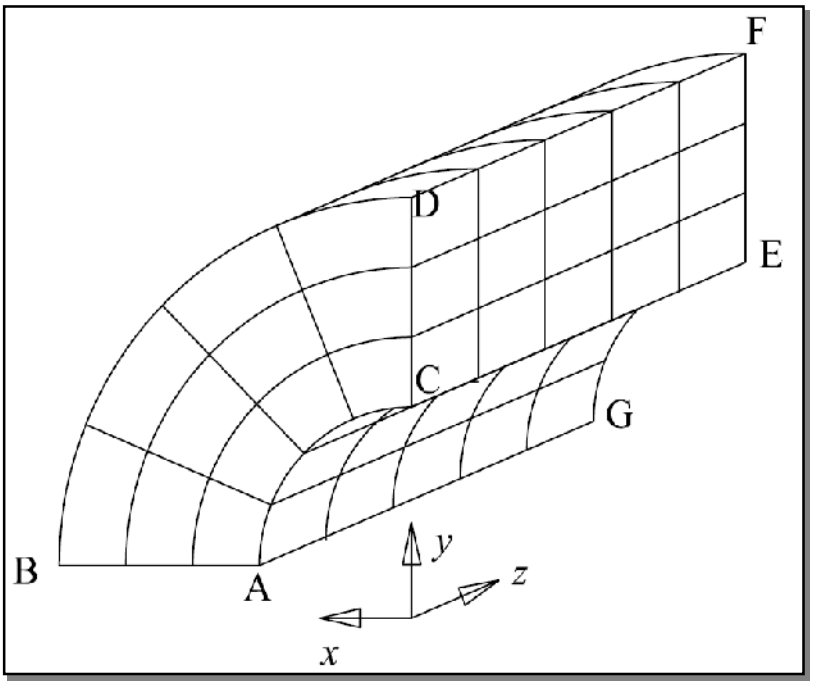


Figure 1: Discretization of a plain cylinder

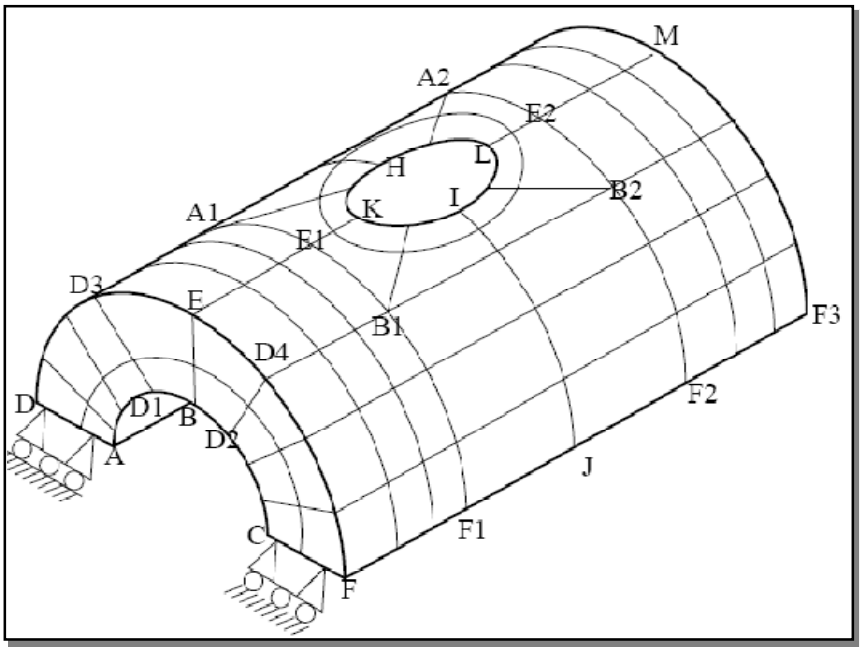


Figure 2 : Discretization of a cylinder with an elliptical cross-bore

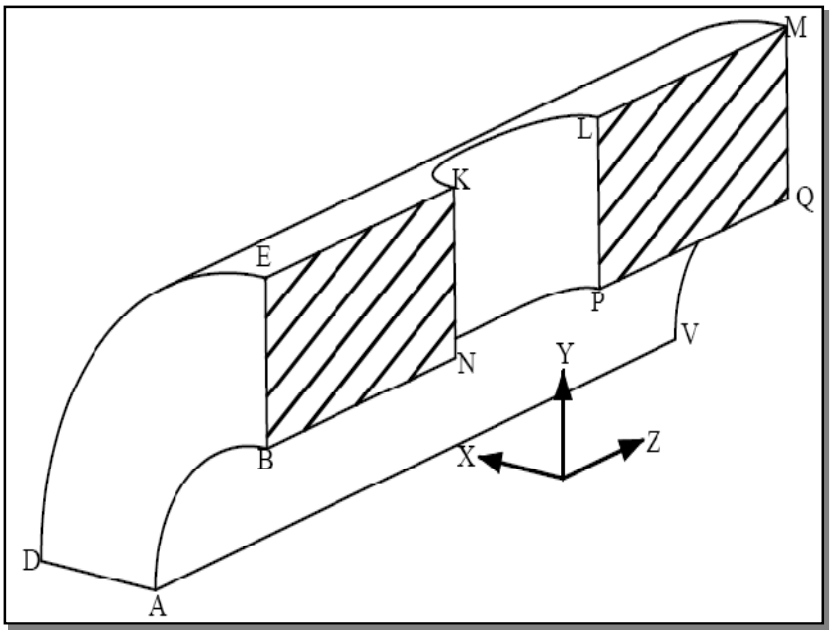


Figure 3 : Meridional cross-sectional view of cylinder with cross-bore

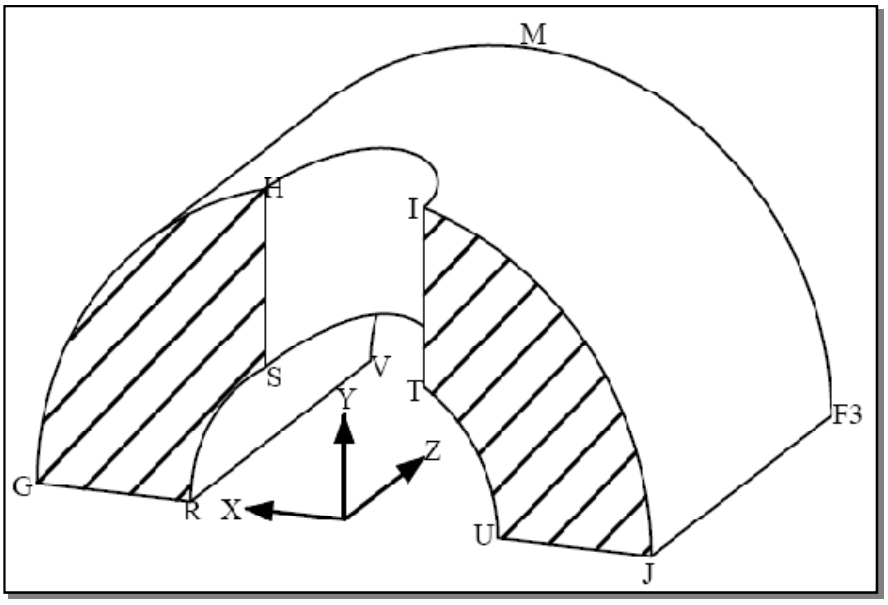


Figure 4: Transverse cross-sectional view of cylinder with cross-bore

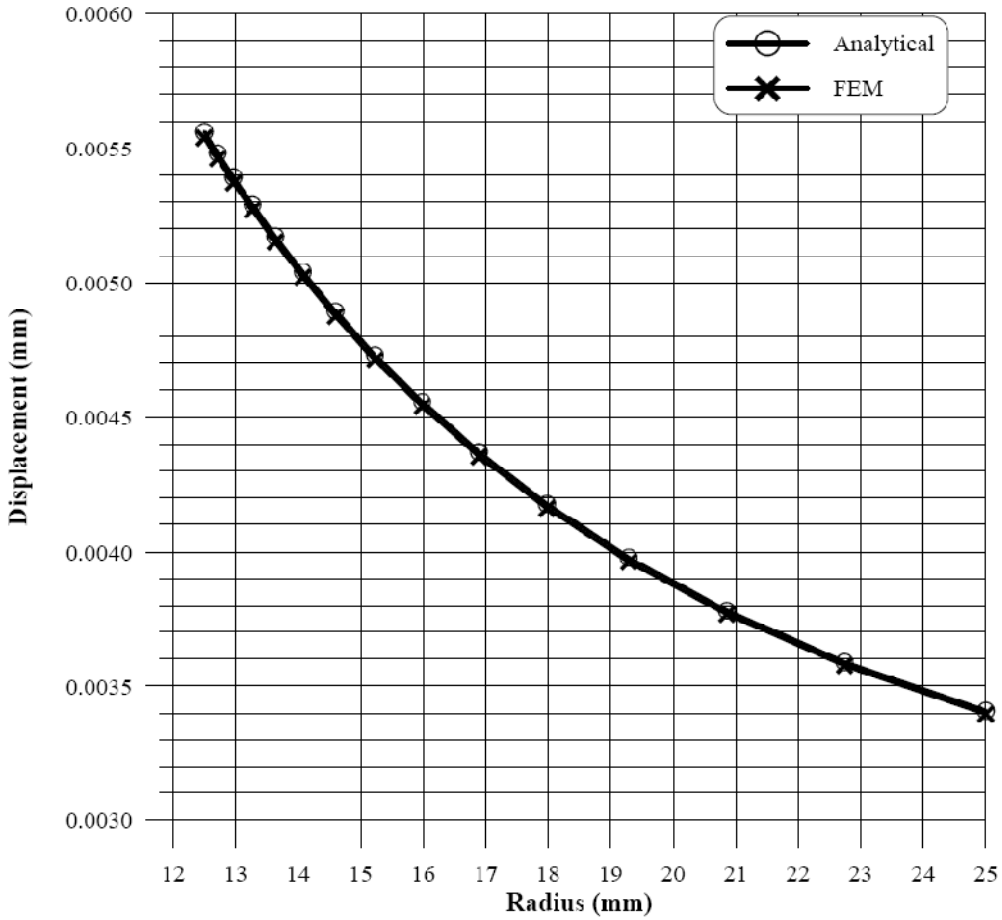


Figure 5: Radial displacement along edge AB or CD

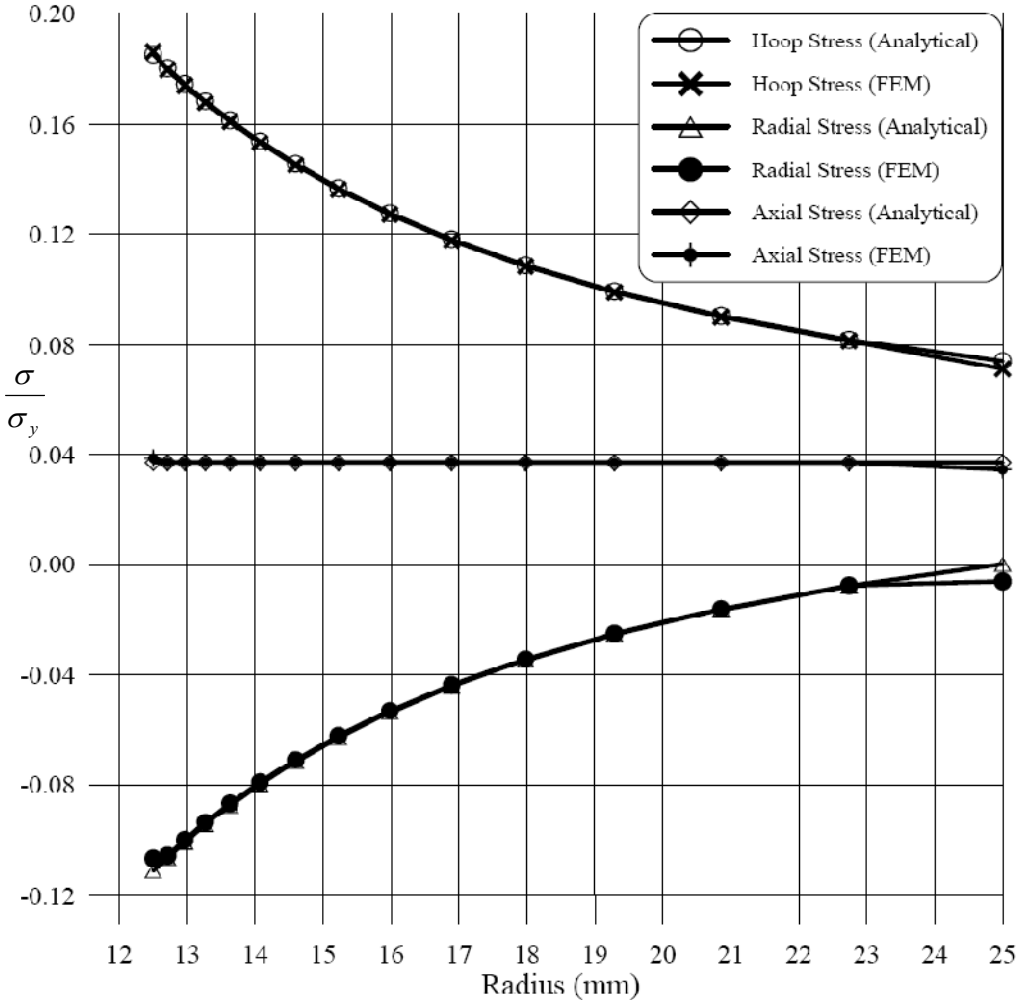


Figure 6: Stress distribution through a plain cylinder wall

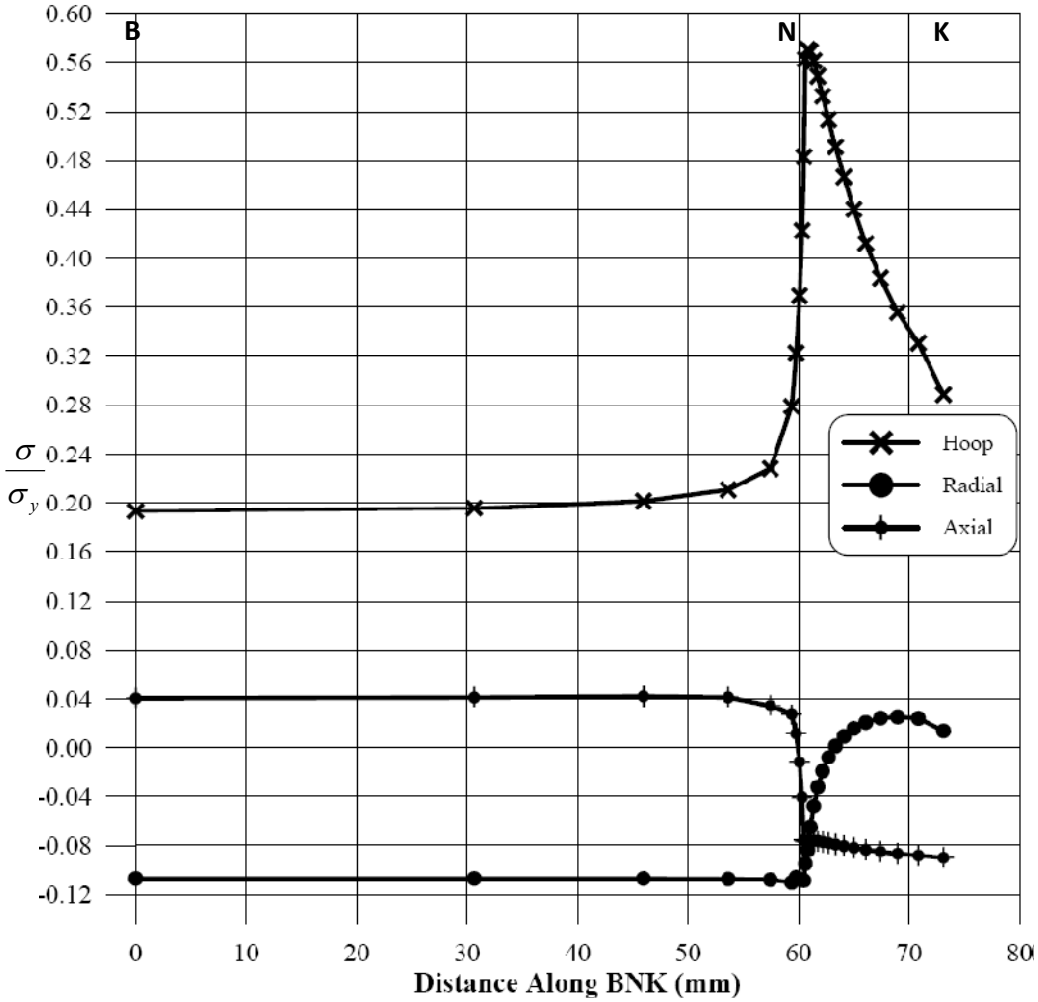


Figure 7: Meridional stresses: circular cross-bore

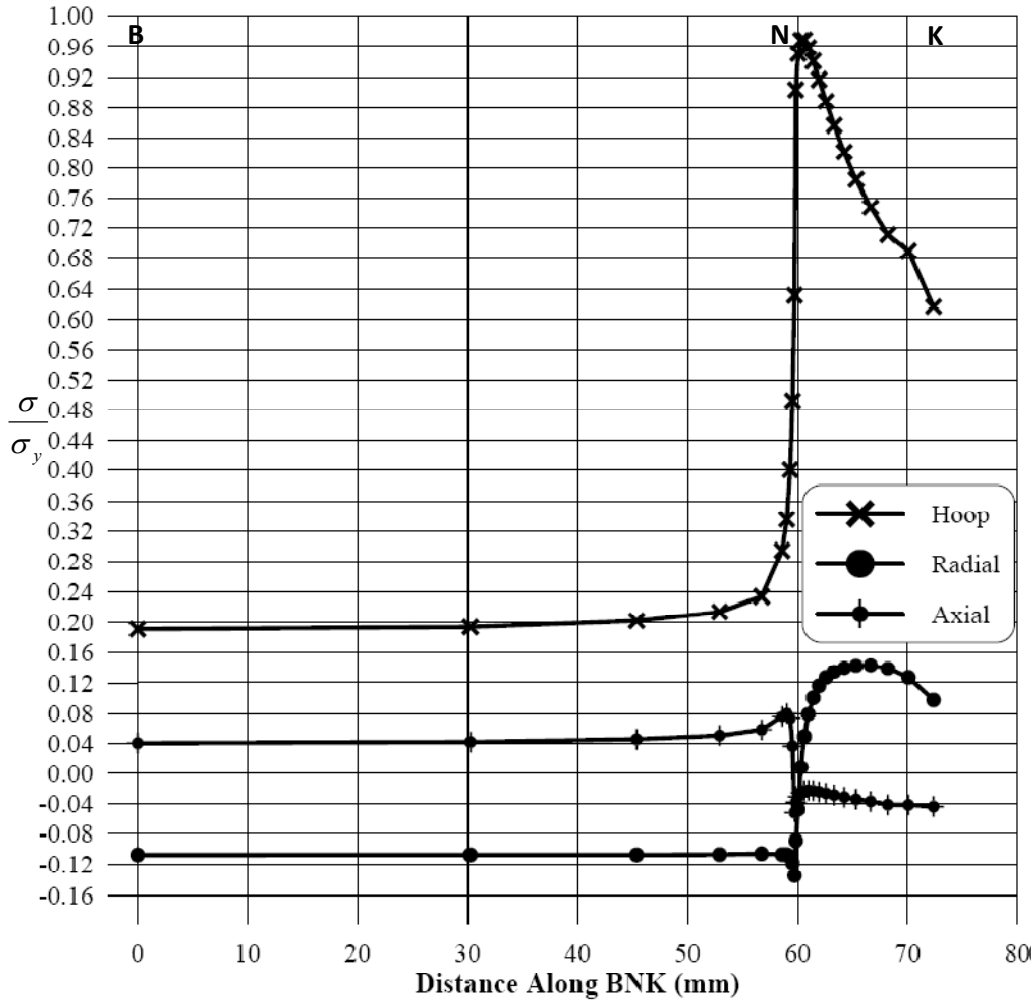


Figure 8: Meridional stresses: parallel elliptical cross-bore

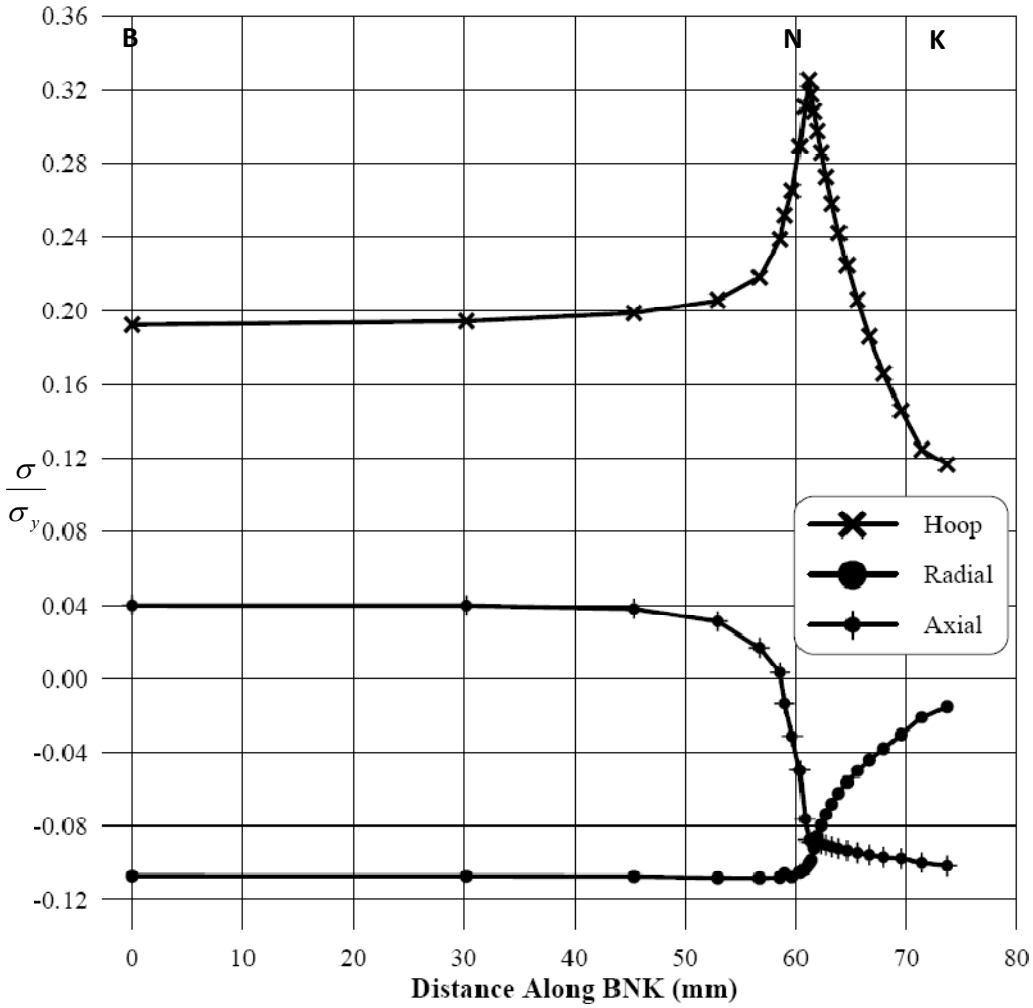


Figure 9: Meridional stresses: perpendicular elliptical cross-bore

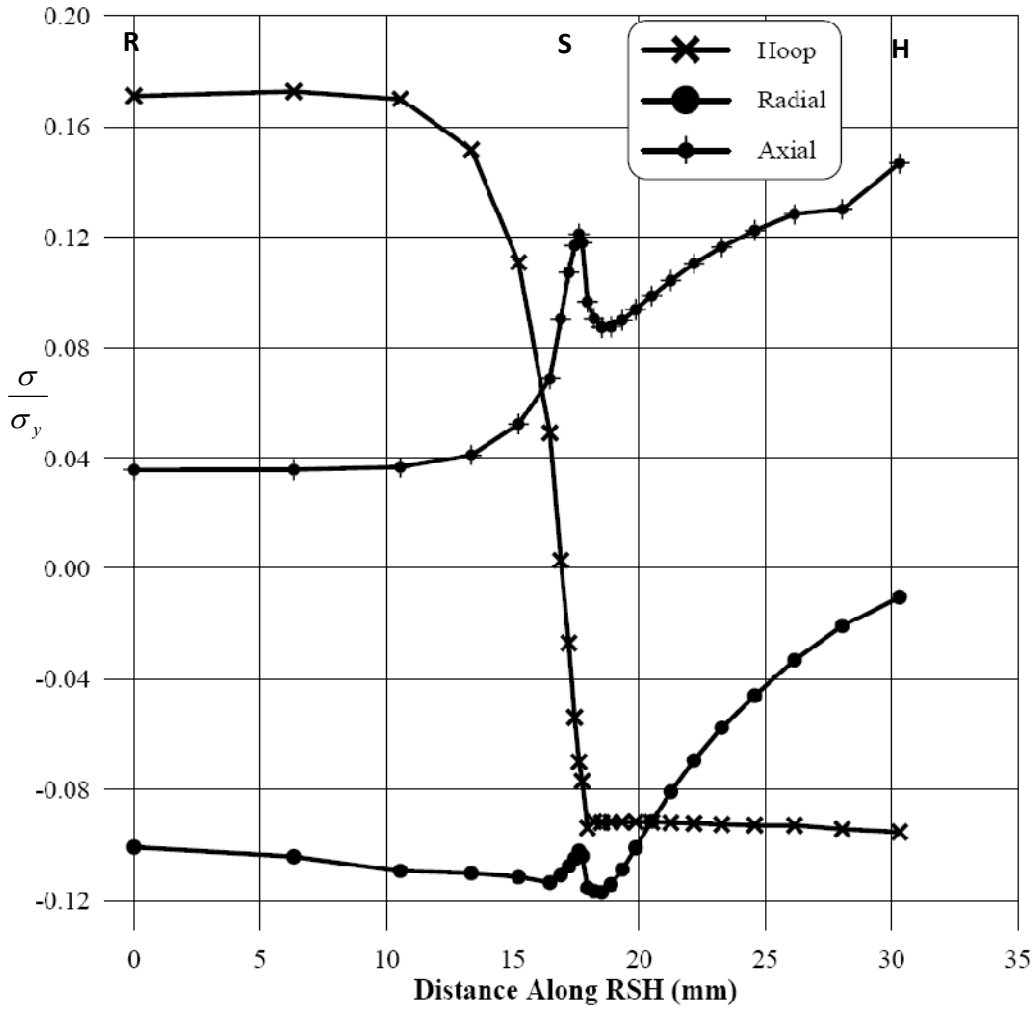


Figure 10: Transverse stresses: circular cross-bore

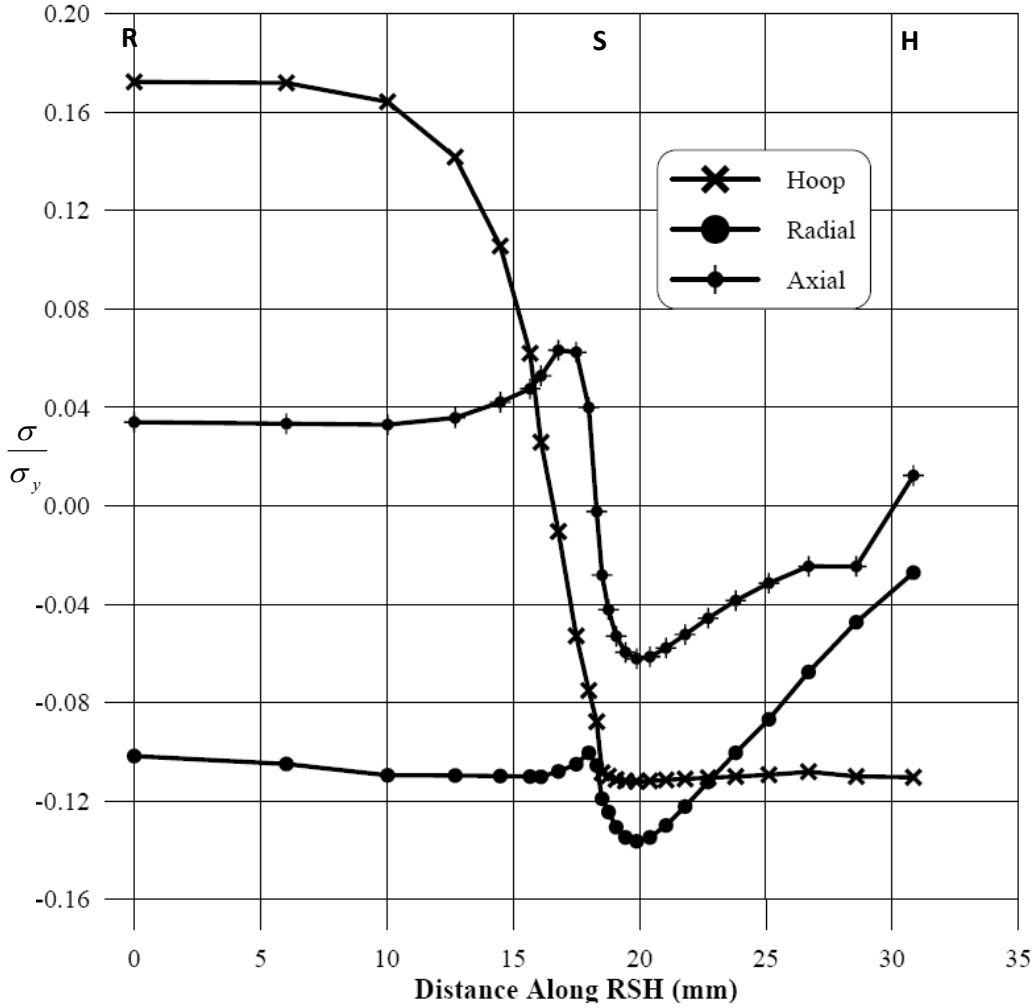


Figure 11: Transverse stresses: parallel elliptical cross-bore

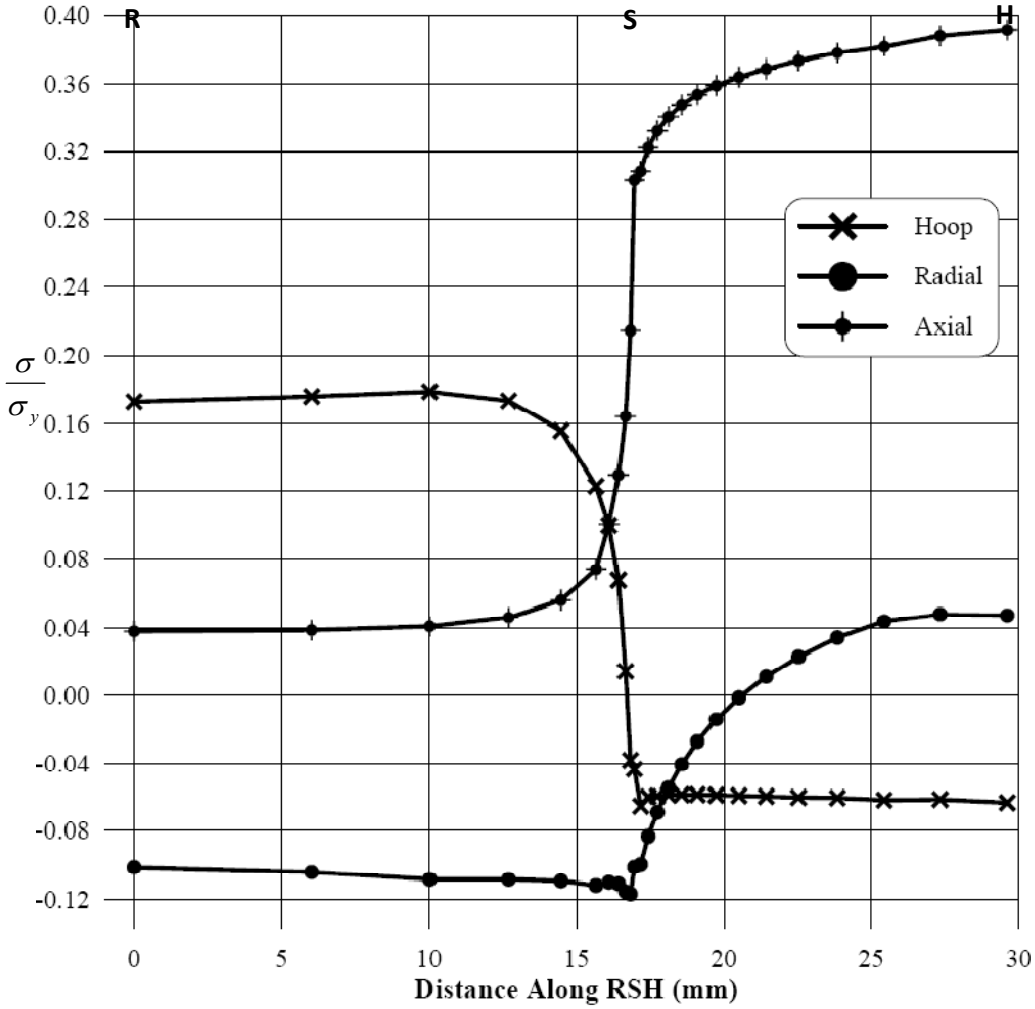


Figure 12: Transverse stresses: perpendicular elliptical cross-bore

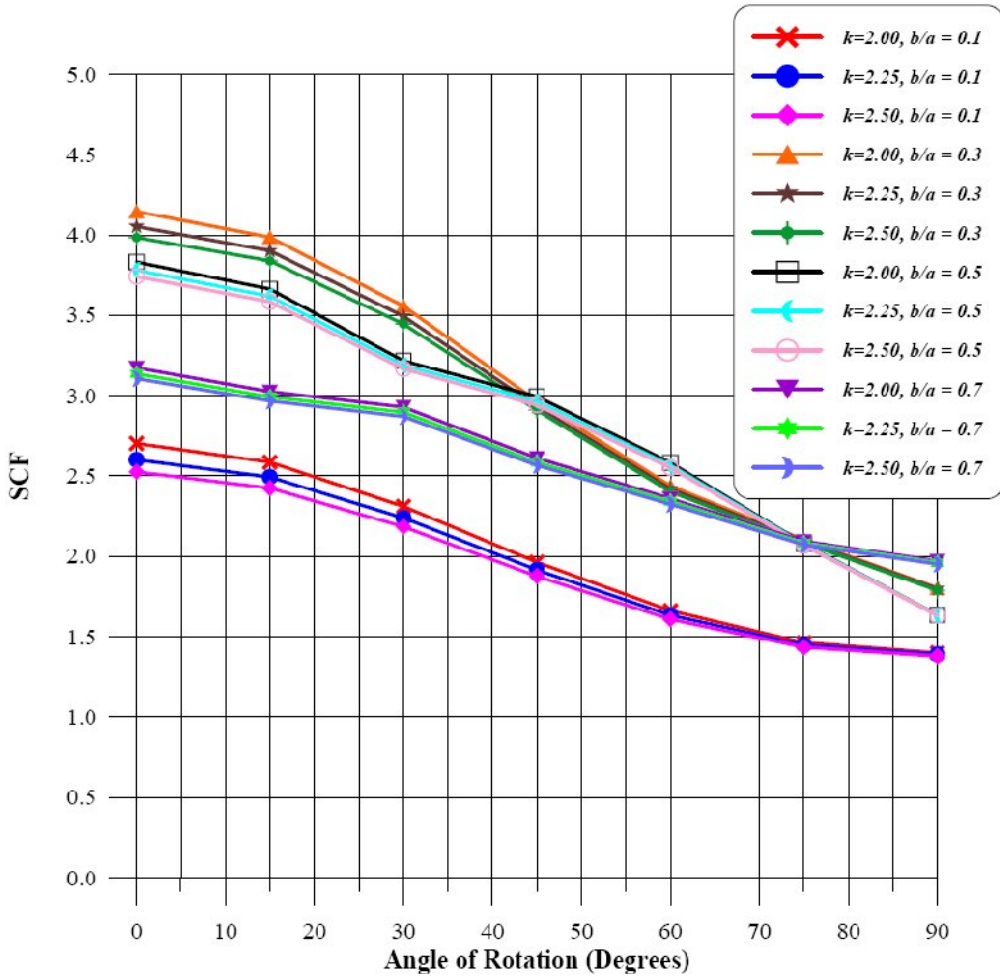


Figure 13: SCF vs. Angle of Rotation for d = 0.15

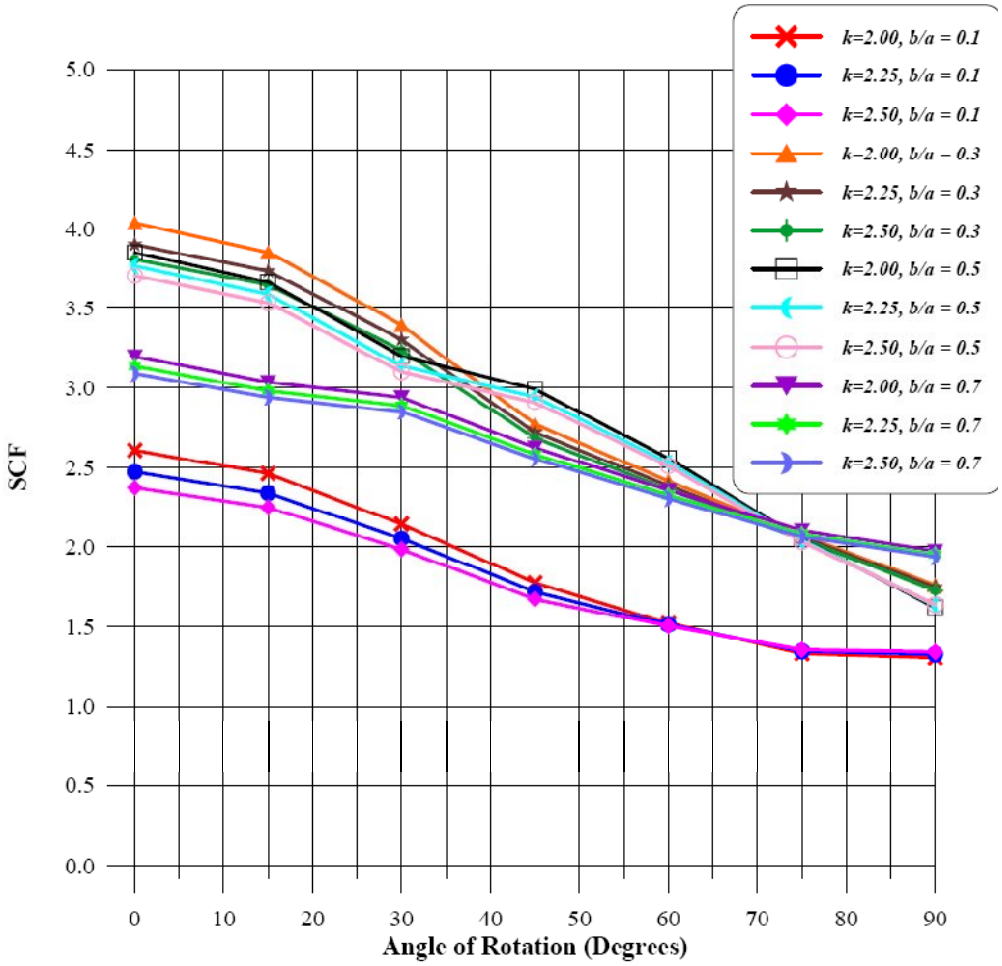


Figure 14: SCF vs. Angle of Rotation for d = 0.20

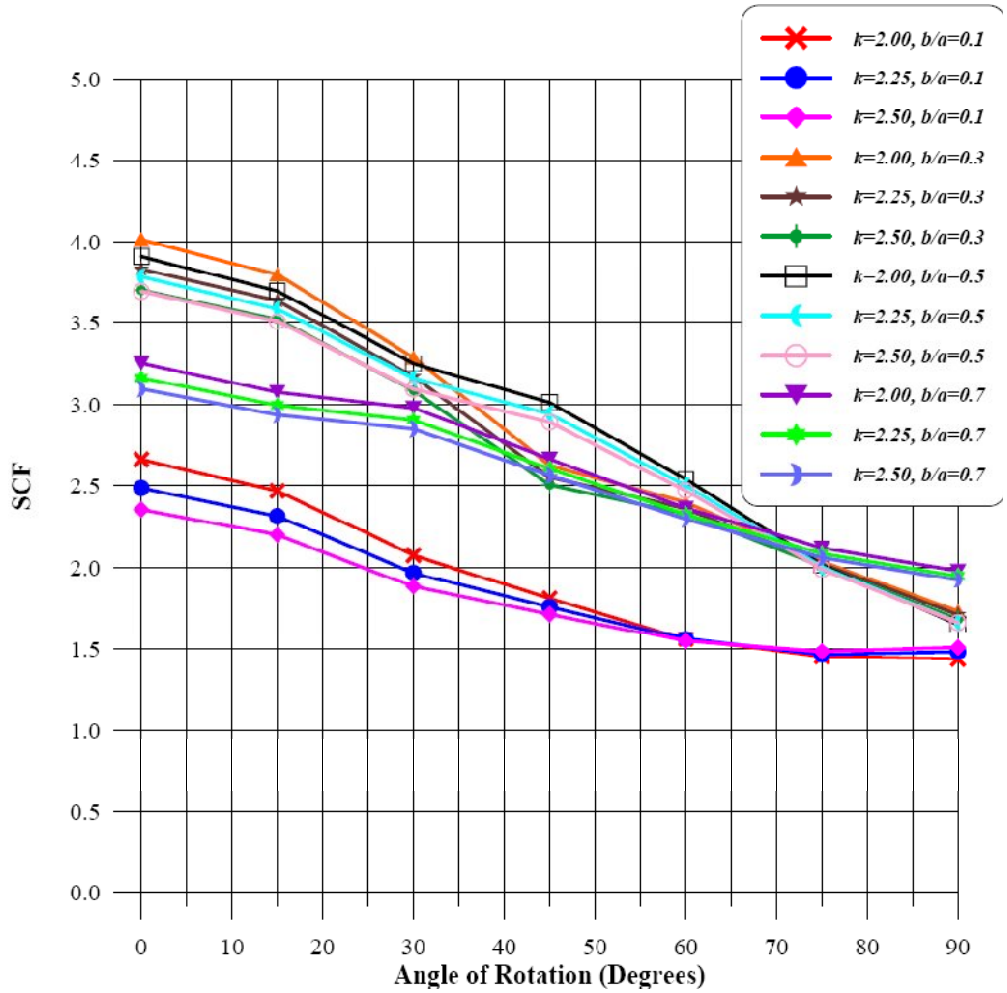


Figure 15: SCF vs. Angle of Rotation for d = 0.25

ANALYSYS OF A FUZZY LOGIC POWER SYSTEM STABILIZER FOR STABILITY ENHANCEMENT

C. M. Mureithi[1], A. Kibet[2], D. Kraus[3] L. M. Ngoo[4], G. N. Nyakoe[5]
School of Electrical, Electronic and Information Engineering, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
Department of Electrical and Electronics Engineering, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: cmmuriithi@eng.jkuat.ac.ke

Abstract
Modern power systems consist of several generators working synchronously to meet the power demand. For reliability of these systems, stability must be ensured incase of faults within the system. Faults within a system induce electromechanical oscillations of the electrical generators. These oscillations, also called power swings, must be effectively damped to maintain the system stability. In an attempt to reduce system oscillations, Power System Stabilizers (PSS) are used to add damping by controlling the excitation system. Studies have shown that a well-tuned PSS can effectively improve power system dynamic stability. The paper demonstrates how the Fuzzy Logic Controller can be used to fine tune the PSS and thus improve the overall stability of a power system. Simulations have been carried out on 16 bus test system found in literature. The model was simulated in a MATLAB/SIMULINK environment. A comparison is carried out on a generator without a PSS, with a PSS and with a PSS plus a Fuzzy Logic Controller. The results indicate that the inclusion of a Fuzzy Logic Controller improves the damping of electromechanical oscillations introduced by a three phase fault in the system, and hence improves the overall stability of the system.

Key words: Fuzzy logic, power system stabilizer, stability

1.0 Introduction

Modern power systems consist of several generators working synchronously to meet the power demand. For reliability of these systems, stability must be ensured incase of faults within the system. Faults within a system induce electromechanical oscillations of the electrical generators. (Hadi, 2002).

Power system stabilizers have been developed to aid in damping these oscillations via modulation of the generator excitation. The art and science of applying power system stabilizers (PSS) has been developed over the past 40 to 45 years since the first widespread application to the Western systems of the United States.

To provide damping, the stabilizers must produce a component of electrical torque on the rotor which is in phase with speed variations. The PSS design is based on the linearised model of the power system (Kundur, 1994).

The application of a PSS is to generate a supplementary stabilizing signal, which is applied to the excitation system or control loop of the generating unit to produce a positive damping. The most widely used conventional PSS is the lead-lag PSS. In this PSS the gain settings are fixed at certain value which are determined under particular operating conditions to result in optimal performance for that specific condition. However, they give poor performance under different synchronous generator loading conditions (Gross; 1986).

The parameters of the conventional PSS (CPSS) are determined based on a linearised model of the power system around a nominal operating point where they can provide good performance. Since power systems are highly non-linear systems, with configurations and parameters that change with time, the CPSS design based on the linearised model of the power system cannot guarantee its performance in a practical operating environment (Sambariya *et al*., 2009). To improve the performance of CPSS, numerous techniques have been proposed for their design, such as using intelligence optimization methods which include simulated annealing, genetic algorithm, Tabu search, fuzzy, neural networks and many other non linear techniques (Sambariya *et al.,* 2009).

This paper proposes to use the Fuzzy Logic Controller in a Multi-machine Power System. Initial studies have been done on the SMIB (Sambariya *et al*., 2009); hence this paper seeks to extend the same to multiple machines operating synchronously. The impact of several controllers is compared under the different faults considered. A comparison is also carried out to compare the impact of the Fuzzy based PSS when the loads are static and dynamic.

2.0 Materials and Methods

The CPSS used in this paper is the Generic Power System Stabilizer (GPSS) simulated in the simulink environment. The GPSS is used to add damping to the rotor oscillations of the synchronous machine by controlling its excitation. The GPSS design is based on the linearised model of the power system (Kundur; 1994)

However the power systems are highly non-linear systems, with configurations and parameters that change with time and the GPSS cannot guarantee its performance in a practical operating environment (Sambariya et al; 2005-2009). Thus the use of a rule-based fuzzy logic controller is recommended. In this paper we compare a rule-based fuzzy logic approach to the common control techniques to a Generic PSS (Kundur; 1994) using the speed deviation $\Delta\omega$ as input, a Generic PSS using the power acceleration P_a as input and a Multiband PSS (Grondin *et al*., 1993).

The fuzzy logic controller can be described by four different parts (El-Hawary1998) which includes: a fuzzification block to transform the input variables to the corresponding linguistic fuzzy

variables with their associated membership values; the fuzzy rule base which specifies the control outputs by using linguistic variables and membership functions to determine the degree of truth of input variables; the fuzzy inference represents the human decision making and processes the fuzzy logic operations of the controller and the defuzzification block converts the linguistic output variables back to numeric values used by the excitation system of the synchronous machine to stabilize the power oscillation. The process of designing a fuzzy logic controller can be split up into five different steps (El-Hawary1998).

Firstly, the relevant input variables are chosen. For controlling the excitation of a synchronous machine the relevant variables are the machine speed deviation $\Delta\omega$ and the acceleration power P_a which is calculated as follows:

$$P_a = P_m - P_e \qquad \text{.....(1)}$$

Secondly, the membership ship functions are defined. A membership function represents the degree of truth of the input signal. For two input signals the degree of truth for each signal is determined and then the maximum of both input signals is taken as the degree of truth. Figure 1 shows the seven set up triangular membership functions for the input variable P_a. A number of 7 linguistic variables are chosen to describe the input and output. For power systems the following linguistic variables have shown to be a good choice: negative big, negative medium, negative small, zero, positive small, positive medium, positive medium and positive big.

Thirdly, a set of fuzzy logic rules has to be implemented. Fuzzy logic rules are expressed as follows:
IF variable IS property THEN action. To derive the rules one can rely on an off-line simulation as described by (Linkens *et al.,* 1990) or input from experts who are familiar with the system to control. It is also possible to use neural networks which have been trained to generate the rules (Antsaklis, 1990). Every entity in Table 1 represents a fuzzy logic rule. The implemented rules can also be represented in a 3D surface view, (see Figure 2). A set of rules which define the relation between the input and output of fuzzy controller can be found using the available knowledge in the area of designing PSS. These rules are defined using the linguistic variables. The two inputs, speed and acceleration, result in 49 rules for each machine. The rules have the following structure: Rule 1**:** If speed deviation is NM (negative medium) AND acceleration is PS (positive small) then voltage (output of fuzzy PSS) is NS (negative small). Rule 2**:** If speed deviation is NB (negative big) AND acceleration is NB (negative big) then voltage (output of fuzzy PSS) is NB (negative big). Rule 3**:** If speed deviation is PS (positive small) AND acceleration is PS (positive small) then voltage (output of fuzzy PSS) is PS (positive small). And so on….

Following the outputs of the evaluated rules have to be combined to represent a single fuzzy logic set. This is done by aggregating the results of the evaluated rules by using the maximum method. In the final step the aggregated output set is defuzzified to represent a real number which is the output of the fuzzy logic. The most common defuzzifaction method is the cendroid method. It returns the center of an area under a curve (the aggregated output set). Figure 3 shows the matlab/simulink model of the excitation system with the various stabilizers. The output of of fuzzy logic controller is fed via the generic power system stabilizer.

Case Study

For the study a fictitious 16 bus system, Figure 9, from literature was used (Gross; 1986). It consists of nine lines, three generators, and seven load points. The three generators are a steam plant located at Rogers, a hydrogenation plant at Russel Dam and a tie line to an external system connected at Lowry substation. The cities Grigsby, Feasterville, Philipsburg and Honnell represent the major load centers. The hydrogenation plant at Russel Dam and the steam plant at Rogers also take significant loads from the system. The parameters of the system are in Appendix 1. The system was modeled in simulink. This system was stable and could perform load flow and thus formed a perfect platform for introducing a Fuzzy Logic based PSS and assess its impact on the system after various fault. For comparison on the effectiveness of the Fuzzy logic based PSS other stabilizers are analyzed as well. The system was subjected to a three phase fault. Firstly the fault was introduced at bus 3 representing small load and then on bus 7 represeting a large load. The impact of the fault on the mechanical power of the machines was plotted against time under various stabilizers. All the static loads were then replaced with a dynamic load and the output were then compared under the two situations.

The total simulation time was set at two seconds. At this time the oscillations of the mechanical power under a Fuzzy Logic based PSS had reached steady state. The fault was set to occur at 13/60 sec and be cleared at 32/60 seconds. The circuit breaker is set to isolate the fault section at 15/60 and reconnect back the load into the system at 35/60 after the fault has been cleared.

3.0 Results

Figure 5 and 6 shows the output active power of the system simulation under fault conditions when the load at Russel dam and Grigsby are isolated during the fault and reconnected back after the fault. This graphs show the comparison of the various stabilizers used in order to determine which produces the best performance in terms of stability whenever a fault occurs. Figure 7 shows the active power outputs when the loads are dynamic and when the loads are static. The sample of time for the system responses was in five seconds. This is acceptable length of time because at this time, most of the system had achieved desired active power that is 1.0 p.u. The comparison was made by looking at the oscillation and also the time taken by each stabilizer to achieve desired value and maintain stability after system subjected to disturbances.

4.0 Discussion and Conclusion

This study shows that it is possible to stabilize power system whenever a fault occurs within the shortest time possible and therefore making the power system more reliable. The settling time reduced after the system subjected to different disturbances. The desired value of the machine output coming in a very short time compared to the conventional stabilizer. The machine with a Fuzzy Logic based Power System Stabilizer Stabilizer when subjected to disturbances achieved the desired values of active power at 0.8 seconds while the machine with a Multiband Power System Stabilizer (MB PSS)achieved the desired value of active power at 1.8 seconds. The other stabilizer take a longer period. This meant Fuzzy Logic based Power System Stabilizer Stabilizer achieved the settling time by 55.56% quicker than Multiband Power System Stabilizer Stabilizer.

Fuzzy Logic based power system stabilizer proved to be the most efficient stabilizer in both cases showing that in order to improve the operation of power systems under different fault conditions effective fuzzy controllers should be fitted. This is applicable in sensitive systems which demand consistent supply of power during exchange in the event of power blackout and thus do not have harmful effects on the system operation.

This study shows that Fuzzy PSS is more superior to the other stabilizers. The replacement of the static loads with the dynamic loads does not affect the settling time of the Fuzzy Logic based Power System Stabilizer.

Improvements in this project include the use of Self tuning power system stabilizer based on artificial neural networks which are used to tune the parameters of the PSS during the real time.

Table 2: Fuzzy logic decision table (Antsaklis; 1990)

	Active power							
Speed deviation		NB	NM	NS	Z	PS	PM	PB
	NB	NB	NB	NB	NS	Z	Z	PS
	NM	NB	NB	NM	NS	Z	PS	PM
	NS	NB	NB	NM	Z	PS	PM	PB
	Z	NB	NM	NS	Z	PS	PM	PB
	PS	NB	NM	NS	Z	PM	PB	PB
	PM	NM	NS	Z	PS	PM	PB	PB
	PB	NS	ZR	ZR	PS	PB	PB	PB

Table 2: System load data

Bus	P (MW)	Q (Mvar)
1	-	-
2	0	0
3	10	55
4	0	0
5	75	15
6	0	0
7	90	20
8	0	0
9	15	4
10	0	0
11	0	0
12	0	0
13	50	2
14	35	3
15	0	0
16	150	20

Table 3: System generator data

Bus	S_r (MVA)	V_{Lr} (kV)	P_G (MW)	Q_{max} (Mvar)	Q_{min} (Mvar)
1	-	345	-	-	-
3	120	13.8	110	80	-40
9	250	13.8	220	140	-100

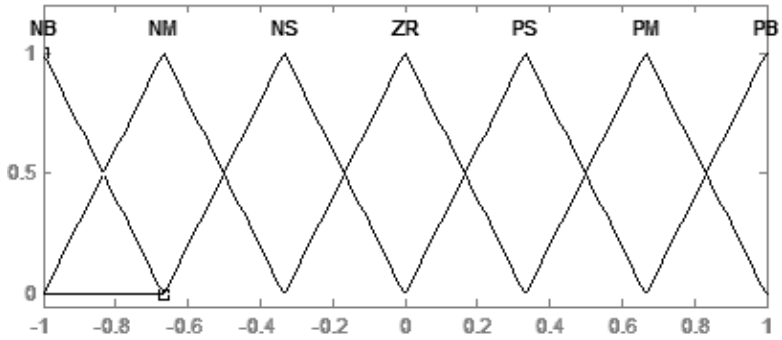


Figure 11: Membership functions for input Pa

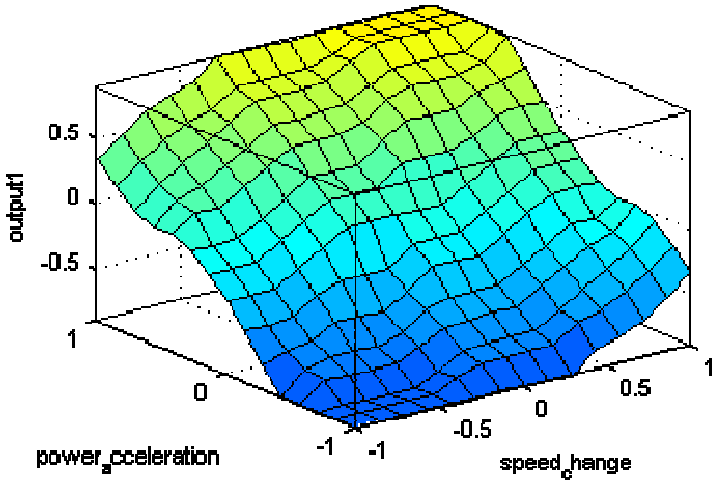


Figure 2: Surface view of fuzzy logic rules

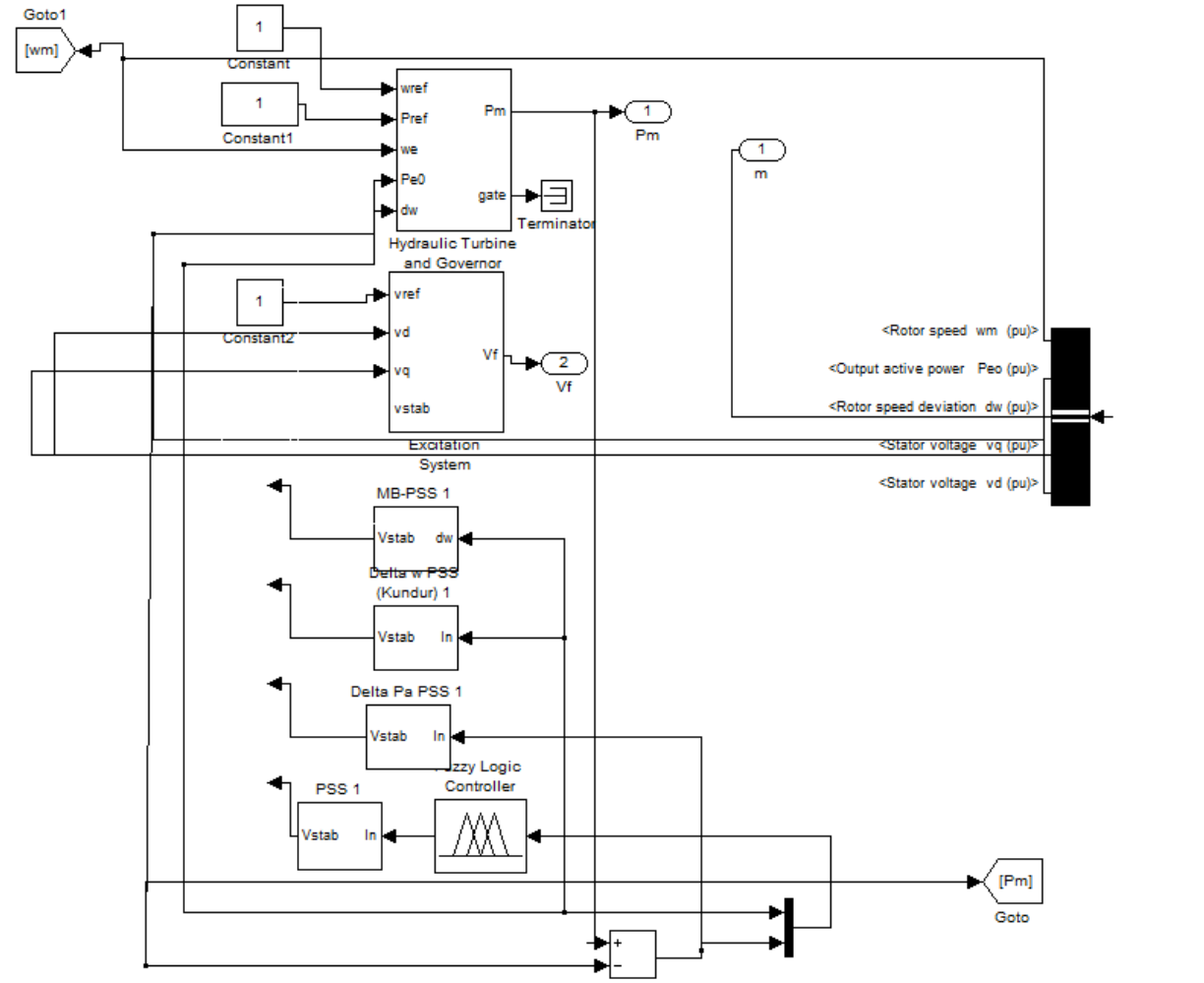


Figure 3: Matlab model of the machines excitation system with 4 power system stabilizers

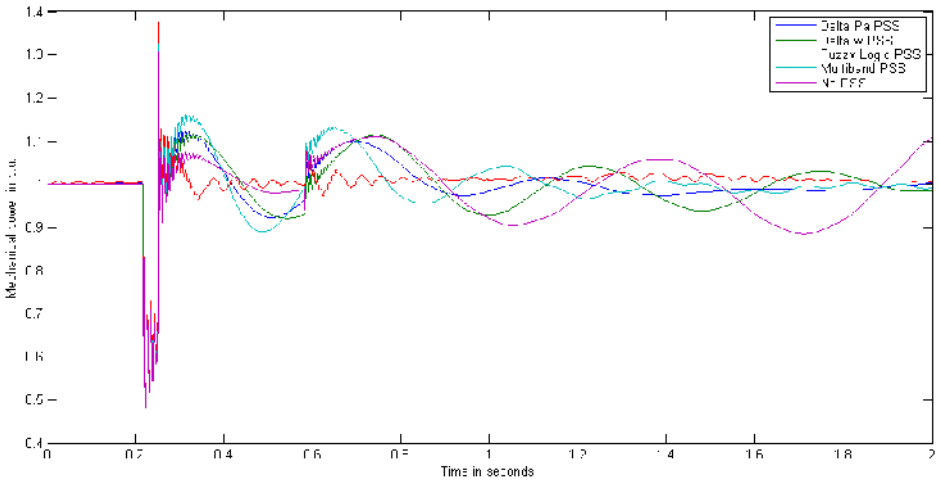


Figure 4: Response of various controllers due to a fault at the 10MW, 55Mvar load at Russel Dam

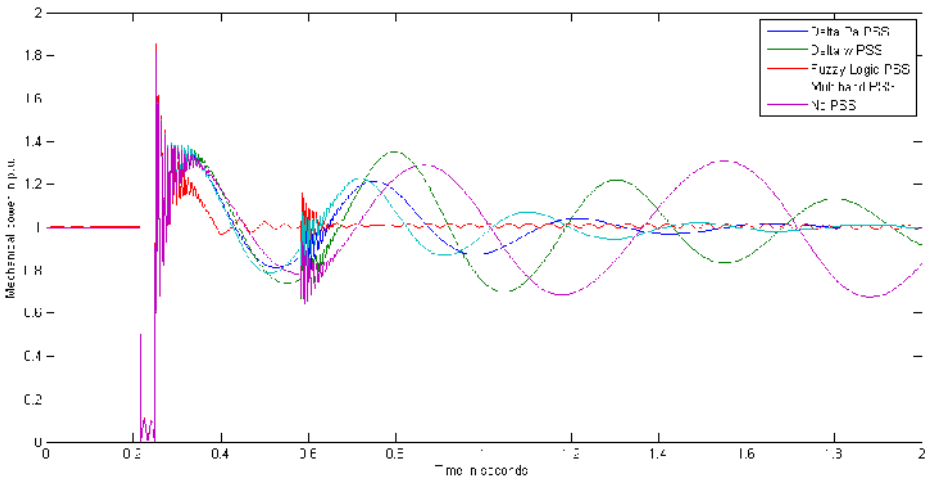


Figure 5: Response of various controllers due to a fault at the 90MW, 20 Mvar load at S. Grisby Substation

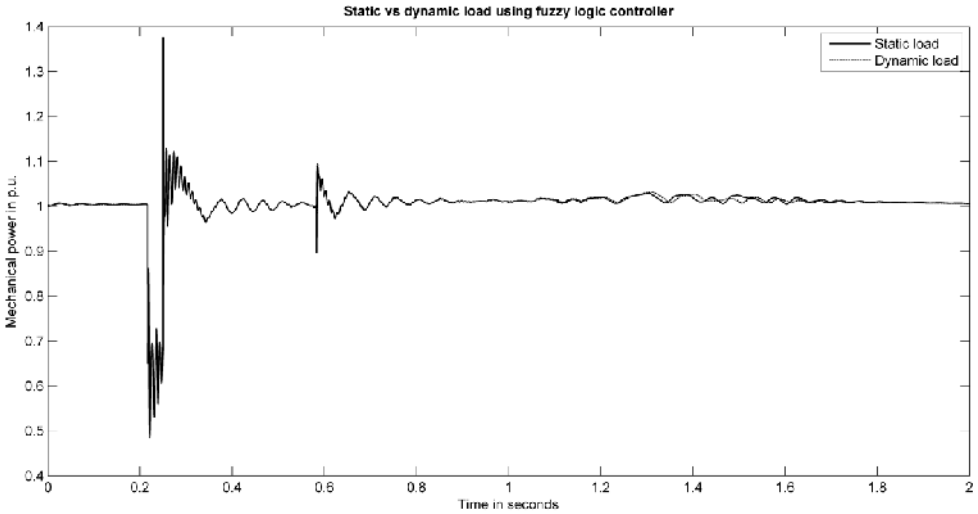


Figure 6: Response of Fuzzy PSS controllers when the 10MW, 55MVar load is static and dynamic

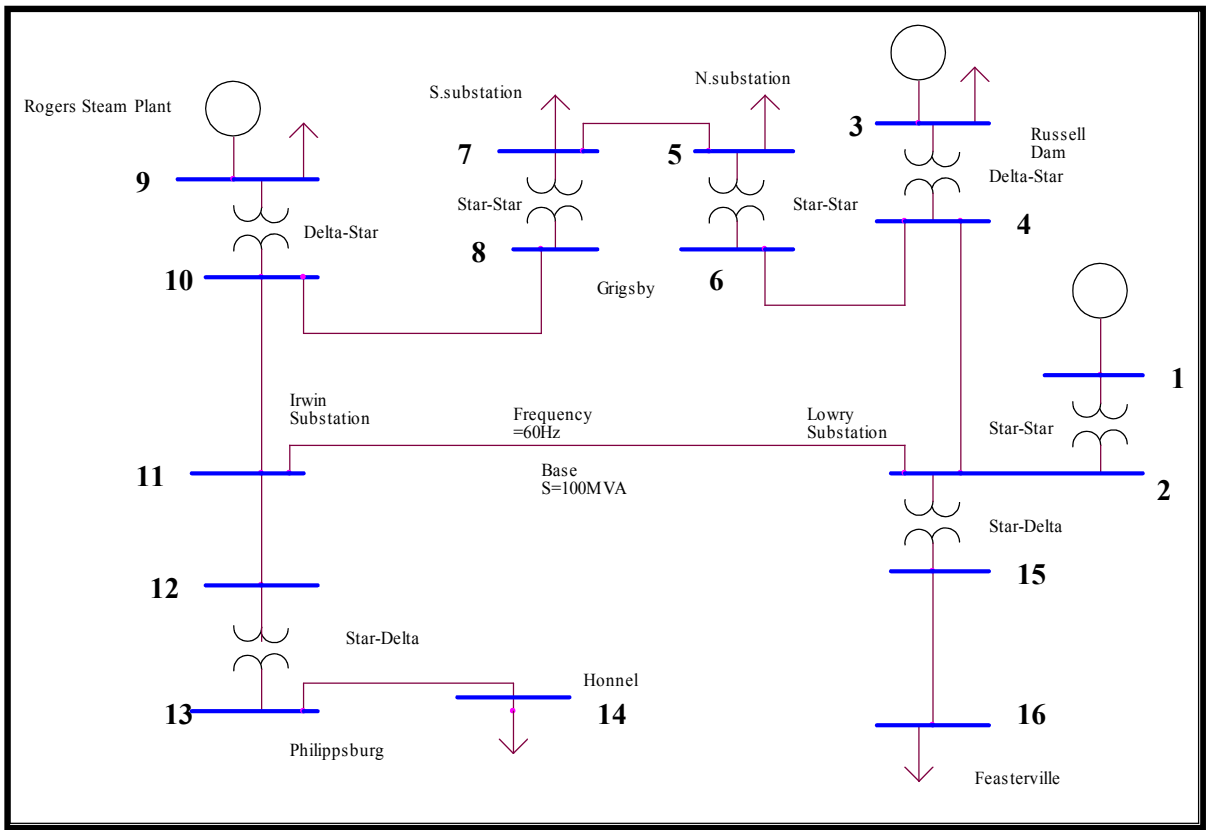


Figure 7: Single line diagram of the 16-bus model

References

Antsaklis, P. J. (1990). Neural Networks in Control Systems, IEEE Control Systems Magazine, Vol. **10**, pp. 3-5.

Charles, G. (1986), Power System Analysis, John Wiler and Sons.

Das, V. V., Stephen, J. and Thankachan, N(2010); "*Power Electronics and Instrumentation Engineering*: International Conference, PEIE 2010,Kochi, Kerala, India,7-9, pp. 10-15.

El-Hawary, M. E. (1998). Electric Power Applications of Fuzzy Systems, IEEE Press, pp. 112-148.

Grondin, R., I. Kamwa, L. Soulieres, Potvin, J. and Champagne R. (1993). An approach to PSS design for transient stability improvement through supplementary damping of the common low frequency," *IEEE Transactions on Power Systems*, **8**(3), pp 954-963.

Kundur P. (1994). Power System Stability and Control. McGraw-Hill, pp 959-1022.

Linkens D. A., Othman M. F. and Mahfouf M. (2001). Designing Power System Stabilizer for multimachine Power System using Neuro-Fuzzy Algorithm" Jurnal Teknologi, **35**(D) Dis. , pp. 55–64.

Sadaat H. (2002). Power System Analysis. McGraw-Hill, -P 691.

Sambariya D. K.; Gupta R.; Sharma A. K.(2005– 2009). Fuzzy Applications To Single Machine Power System Stabilizers. *Journal of Theoretical and Applied Information Technology*, pp 317-324.

Appendix 1

Transmission Line Parameters

R1= 0.01273 Ohms/km, R0=0.3864 Ohms/km
L1=0.9337 mH/km, L0=4.1264 mH/km
C1=12.74 nF/km, C0=7.751 nF/km
Line length: 156km

Base Voltage Specifications

345kV	Bus 1
230kV	Bus 2, 4, 6, 8, 10, 11 and 12
115kV	Bus 5, 7, 15, 16
69kV	Bus 13, 14
13.8kV	

DESIGN AND SIMULATION OF A FUZZY LOGIC TRAFFIC SIGNAL CONTROLLER FOR A SIGNALIZED INTERSECTION

C. M. Mwangi, S. M. Kang'ethe, G. N. Nyakoe
Department of Electrical and Electronic Engineering, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: maina.charles@gmail.com

Abstract
Traffic control and management poses a major problem in many cities, especially in rapidly growing and motorizing cities like Nairobi, Kenya. Currently, fixed-cycle controllers are being used in all signalized intersections in Nairobi. This has culminated in most intersections within the city almost grinding to a halt during peak hours. The efficiency of traffic flow through an intersection depends on the phases, sequence and the timing of the traffic signals installed. This paper proposes a fuzzy logic system to control traffic signals on a signalized intersection. The Fuzzy Logic Controller (FLC) dynamically controls the traffic light timings and phase sequence to ensure smooth flow of traffic, decrease traffic delays and thus increase the intersection capacity. In the design, vehicle detectors are placed strategically upstream and downstream to determine traffic density and the delay on each approach. This traffic data is then used by the FLC to determine whether to extend or to terminate the current green phase and to select the appropriate phase sequence. A fuzzy logic traffic control simulation model is developed and tested using MATLAB/ SIMULINK software. The performance of the Fuzzy Logic traffic controller is then compared to that of the fixed-cycle controller. The performance of FLC is found to be similar to that of the fixed controller in normal traffic conditions. However, in heavy traffic conditions, FLC results shows 25% decrease on average delay of cars waiting at the intersection and 6% improvement on total number of cars served at the intersection over the same simulation period compared to the fixed cycle controller. The results show that there is a huge improvement that can be realized by using FLC in controlling traffic flow at intersections.

Key words: Traffic control, Traffic flow, Signalized intersection and Fuzzy logic controller

1.0 Introduction

Optimization of the functioning of traffic signal is considered one of the most effective measures to address traffic congestion. However, the optimization of signal timing is complex due to randomness, complexity and nonlinearity of the transportation system. Fuzzy logic is suitable for controlling intersections, especially those with heavy traffic, because it is able to emulate the control logic of traffic police officers who sometimes replace traffic signal control when the intersection is congested [1].

The earliest known attempt to apply fuzzy logic in traffic control was made by Pappis and Mamdani [2]. They implemented a fuzzy logic controller in a single intersection of two one-way streets. Ever since, much similar research has been done and generally reported better performance of the fuzzy logic controllers compared to the pre-timed controllers [3-9]. This paper presents a fuzzy traffic signal control system which seeks to improve the intersectional capacity of signalized intersections by increasing the vehicle throughput while reducing their delay at the intersection.

This paper is organized as follows. In section II, description of fuzzy logic traffic signal control system for a signalized intersection is presented. To evaluate the performance of the controller, the simulation of the fuzzy logic traffic signal control model is carried out in section III. The results of the simulation FLC system is compare to the fixed-time controller and discussions of these results are presented in section IV. The conclusions of the paper are given in the last section.

2.0 Materials and Methods

2.1 Design of Traffic Control System

The general structure of the fuzzy traffic lights control system model will have the structure shown in figure1. The fuzzy traffic light control system will utilize two sets of inductive loop sensors on each approach to the intersection; one just before the intersection and the other a predetermined distance from the intersection to gather traffic data information.

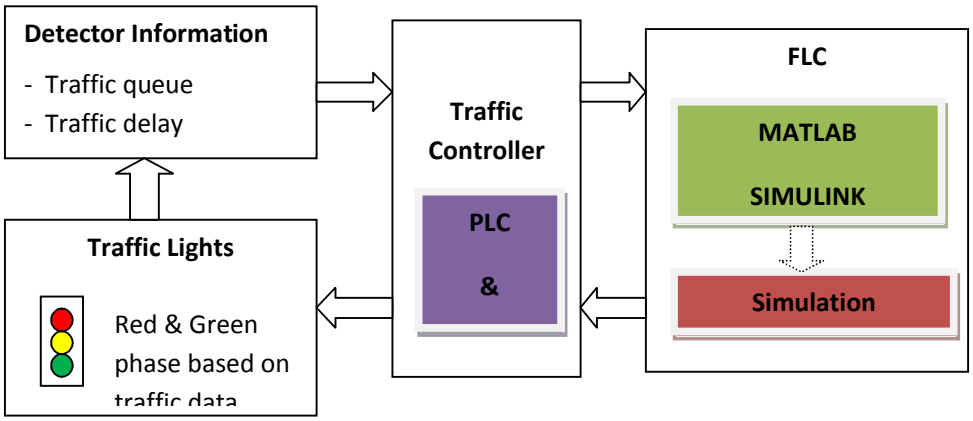


Figure 1: A general structure of the fuzzy traffic lights control system model

This traffic data information will be used by the fuzzy logic controller to select the phase with highest priority and also to determine whether to extend the current green phase. The information on the selected phase and/or extension time from the FLC will be inputted to the PLC for actuation. The sensors and traffic lights are connected to the Programmable Logic Controller (PLC) via the relay interface and protective devices.

2.1.1 Intersection Structure

The structure of intersection is based on Lang'ata/Mbagathi signalized roundabout which has four approaches as illustrated on figure 2. The roundabout has four approaches: Lang'ata road (from Nairobi), Mbagathi road, Lang'ata road (from Wilson airport) and Mai Mahiu road. Inductive loops for vehicle detection are installed on the stop lines and 100m upstream on each approach to collect traffic data. The amount of vehicles in each approach will be determined by the difference of the readings between the two sensors.

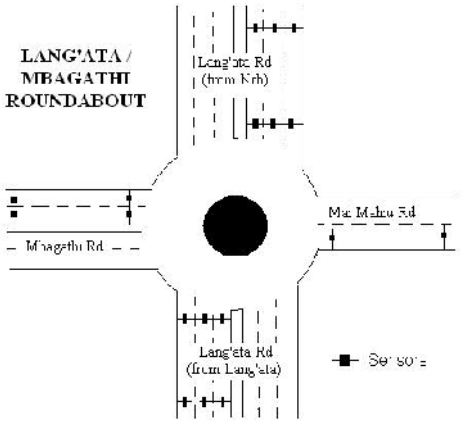


Figure 2: Overview of Lang'ata/Mbagathi Roundabout

2.1.2 Input and Output Parameters

The fuzzy logic system will use information from the inductive loop sensors to determine the number of cars between the two set of the sensors. This will provide the controller with traffic densities in the lanes and allow a better assessment of changing traffic patterns. The input and output parameters for the fuzzy logic traffic signal controller for this paper are as follows:

Input parameters of the phase selection and green phase extension model

- Queue Length in Red Signal [QR] (short, medium, long)
- Waiting Time of Longest Queue in Red Signal [WR] (short, medium, long)

Output parameters of the phase selection and green phase extension model

- Next phase with highest priority [W(p)] (Fuzzy)
- Green phase extension or termination [Ext] (Embedded MATLAB)
- Selection of the next phase based on Weight [P] (Embedded MATLAB)

2.2 Simulation of Fuzzy Logic Traffic Controller

In this paper, MATLAB and SIMULINK programming environment is used to develop the simulation model. The simulation model is developed using Simulink, Fuzzy Logic and SimEvents toolboxes as well as MATLAB workspace environment.

The fuzzy logic controller determines phase sequence and whether to extend or terminate the current green phase based on a set of fuzzy rules. The fuzzy rules computes the phase with the highest degree of priority based on queue length and waiting time and then uses this traffic data to select the phase and determine the duration of green phase extension, if any.

2.2.1 General Structure of the Simulation Model

The selection of the phase with the highest priority is achieved by using SIMULINK sub-system blocks representing each approach as shown in figure 3. The priority level of each approach is generated using the FLC block. The outputs the approaches sub-systems are combined into the traffic signal intersection block that comprises of the FLC control unit and the input switch block. The input switch block selects the approach to be granted the green phase based on the FLC control unit.

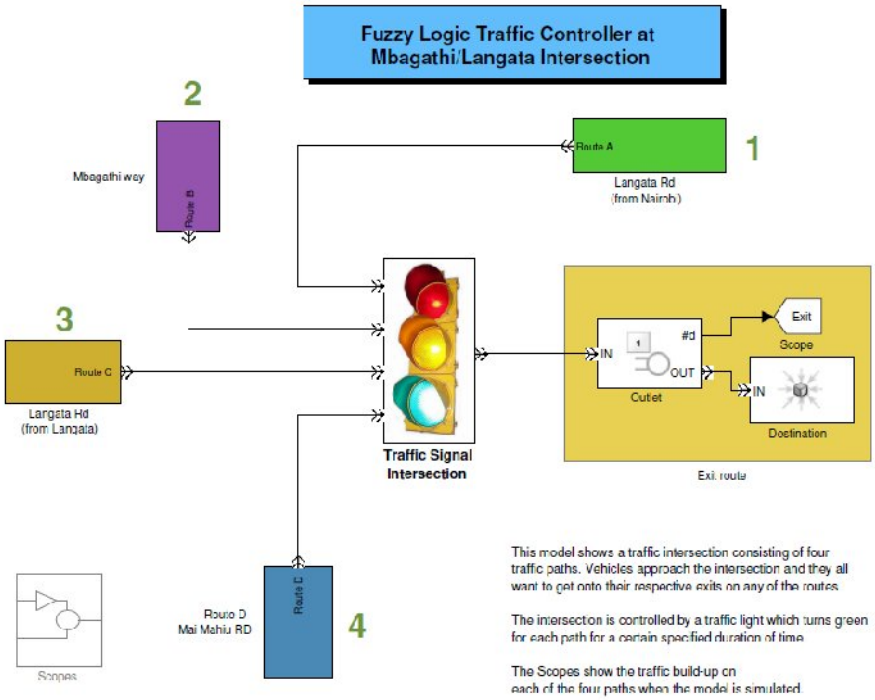


Figure 3: General structure of the FLC Traffic control model

2.2.2 Weight or Priority of Phase

The priority or weight of an approach is derived from determining the delay and the number of queuing vehicles in each of the approaches. It is assumed that initially the approach "A" is given right of way i.e. green signal is given to the vehicles on approach "A". Figure 4 shows the internal structure of each of the intersection approach sub-system.

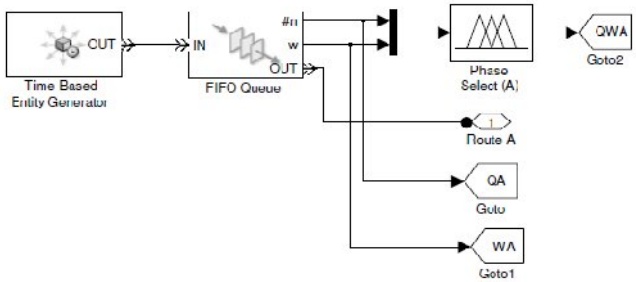


Figure 4: FLC subsystem model of each approach

The input and output parameters used on the FLC block to determine the level of priority of each approach are:

Input Parameters:

QR - Queue length in Red phase (Short, Medium, Long)

WR – Waiting time in longest queue in Red (Very Short, Short, Medium, Long)

Output Parameter:

W(p) – weight or level of priority of phase

The membership functions (MFs) of the fuzzy sets of the input and output parameters for the next phase and Green phase extensions are represented using Gaussian MFs. The fuzzy rules for determining the approach with the highest degree of priority or weight are illustrated in Table1. The fuzzy rules are identical for all the four approaches.

Table 1: Fuzzy rules of Weight of Red Phase

No	FUZZY RULES
1.	IF {QR is Short} AND {WR is Short} THEN {W(p) is Low}
2.	IF {QR is Short} AND {WR is Medium} THEN {W(p) is Low}
3.	IF {QR is Short} AND {WR is Long} THEN {W(p) is Medium}
4.	IF {QR is Medium} AND {WR is Short} THEN {W(p) is Low}
5.	IF {QR is Medium} AND {WR is Medium} THEN {W(p) is Medium}
6.	IF {QR is Medium} AND {WR is Long} THEN {W(p) is High}
7.	IF {QR is Long} AND {WR is Short} THEN {W(p) is Medium}
8.	IF {QR is Long} AND {WR is Medium} THEN {W(p) is High}
9.	IF {QR is Long} AND {WR is Long} THEN {W(p) is High}

2.2.3 Next Phase Selector

Determining the next green phase is based on a set of If-Then Embedded MATLAB code rules, some of which are illustrated in Table2. The If-Then rules determine the current phase and use the traffic data depicting the weight of the other phases from the fuzzy logic unit to determine the next phase. The candidate red phase approach with highest priority degree is selected. The default green phase of the system is approach A.

Table 2: Part of Embedded MATLAB rules of the Green Phase Selector

```
&& Phase Selection

function y = fcn(a, b, c, d, p)

%% Phase A

  if ((p==1) && (b<=4) && (c<=4) && (d<=4))

    y = 2;

  elseif ((p==1) && (b<=4) && (c<=4) && (d>4))

    y = 4;
```

2.2.4 Green Phase Extension

Determining whether to extend or terminate the current green phase is based on a set of If-Then Embedded MATLAB code rules. The If-Then rules compares the traffic condition with current green phase and traffic condition with the other candidate green phase (the red phase with the highest priority degree). Each phase has a minimum green time (T_{min}) of 20sec and a maximum green time (T_{max}) of 30sec. Some If-Then rules for the Green Phase extension are illustrated in Table3.

Table 3: Embedded MATLAB rules of the Green Phase Extender

```
&& Phase Extension

function ext = fcn(a, b, c, d, p)

%% Phase A

  if ((p==1) && (b<=4) && (c<=4) && (d<=4))

    ext = 0;

  elseif ((p==1) && (b<=4) && (c<=4) && (d>4))

    ext = 5;
```

2.2.5 Fuzzy Logic Control Unit

The fuzzy logic control unit (figure 5) forms the brains that control the selection and extension of the green phase. Inputs depicting the weight or level of priority on each approach are inputted to the phase extension sub-system which determines whether to extend or terminate the green phase. The value from the phase selection sub-system is added to the T_{min} (20sec) to get the duration of the green time extension, T_{Ext}, which is used as an attribute for determining the server duration. Every time an entity is served by the server, a function call is generated which activates the phase selected by the phase selector subsystem.

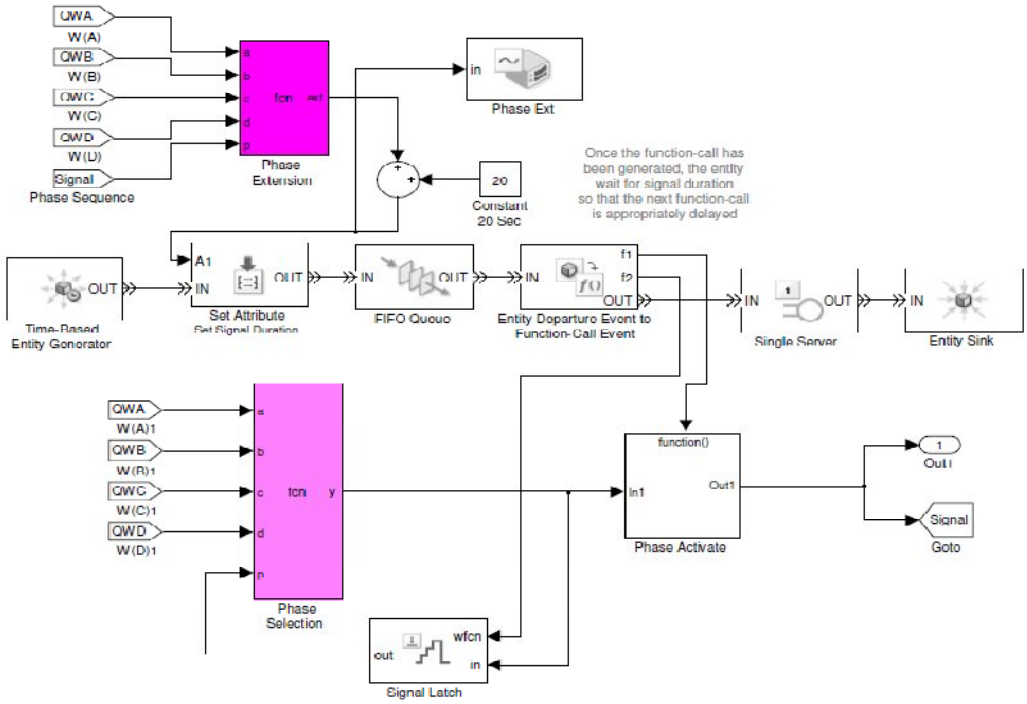


Figure 5: FLC control unit of Simulation model

3.0 Results and Analysis

The simulation for the fuzzy logic traffic signal controller is carried out using MATLAB, SIMULINK and the Fuzzy Logic Toolbox. The developed Fuzzy logic model is compared with fixed-time controller. The simulator is run for 1000 seconds with the following conditions:

(i) The arrival of vehicles on each approach is A(3), B(5), C(2) & D(6).

(ii) The green time (in sec) of each phase is determined by the server

- Fixed-time controller: A(30), B(30), C(30) & D(20)
- FLC: min (20) and max (30)

3.1 Results

The results of the simulation of the vehicles on each approach using fuzzy and fixed-time controllers are illustrated in figure 6. It can be seen that the length of queues in fixed-time controller are longer than those of the fuzzy controller. Figure 7 shows the average vehicle delay at the intersection. It can be seen that vehicles spend more time in an intersection using fixed-time controller than the one using Fuzzy controller.

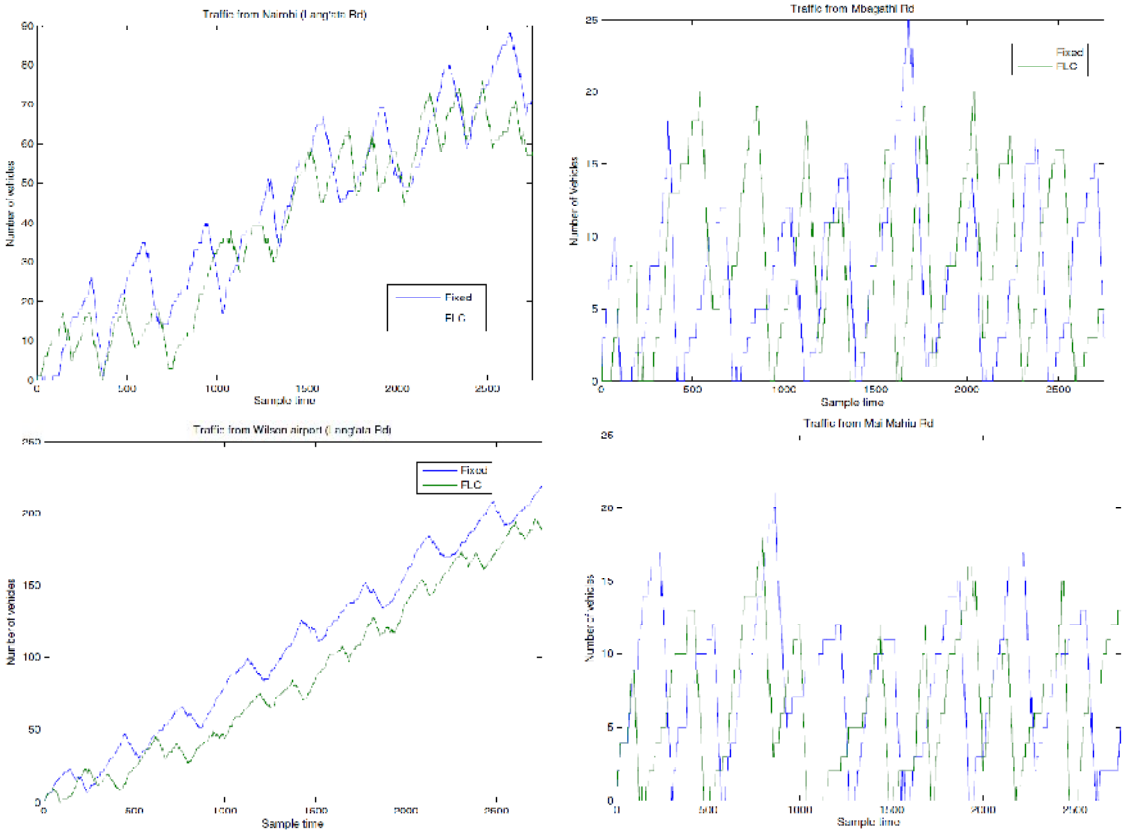


Figure 6: Traffic queues on each approach of the intersection

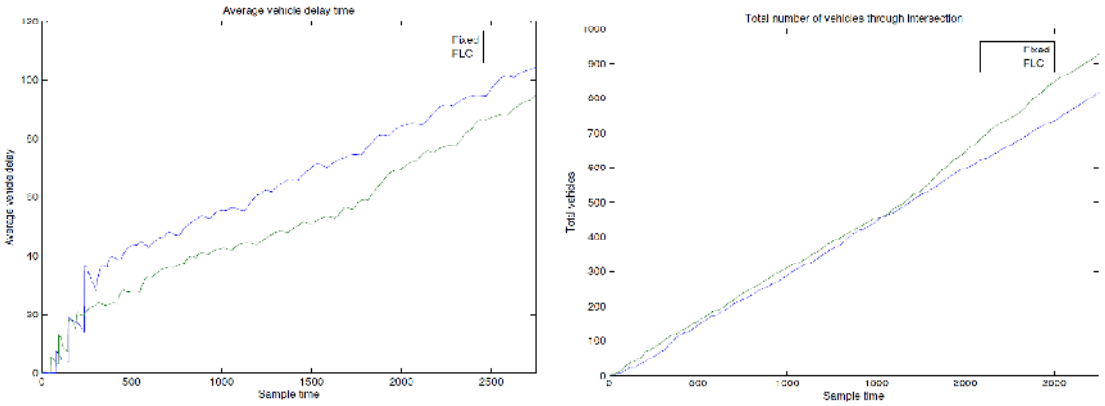


Figure 7: Traffic queues on each approach of the intersection

Figure 8 shows the phase sequences of the fixed-time controller and fuzzy controller. It can be seen that the sequence of fixed-time controller follows the sequence of 1-2-3-4 representing the four approaches. The phase sequence of the fuzzy controller is dictated upon by the weight of each phase with the one with highest priority granted green phase. Figure 9 shows the extension duration granted again based on the weight of the green phase.

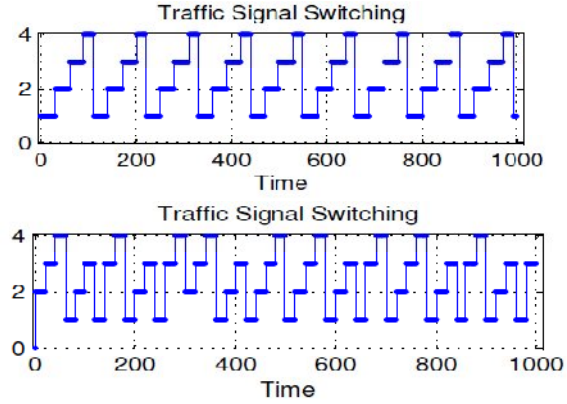


Figure 8: Phase sequence of the controllers at the intersection

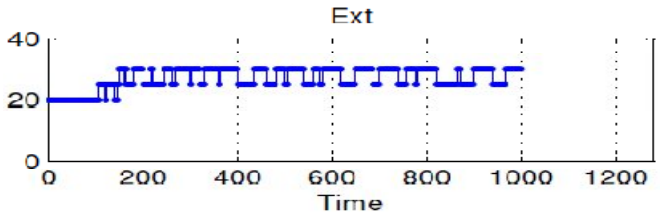


Figure 9: Phase extension duration of the Fuzzy Controller at the intersection

3.2 Analysis

The performance comparison between fixed time controller and fuzzy traffic controller is summarized in Table 4. As can be seen, the fuzzy logic controller shows about 25% decrease in time on average vehicle delay at the intersection and about 6% increase on the total number of cars being served at the intersection.

The graphs on figure 6-9 clearly show that as traffic volume increases the fixed-time controllers perform much poorer that the fuzzy controller. The fuzzy controller is able to increase the green time to cater for the increasing traffic. When handling low volumes of traffic, both controllers perform more or less the same with the fixed controller. However, as the traffic volumes increase considerably, the performance of the fixed-time controller reduces compared to that of the fuzzy logic controller.

Table 4: Simulation results for Fixed-time and Fuzzy Logic Controller

Simulation parameters	**Fixed Controller**	**Fuzzy Logic**
Simulated time (in sec)	1000	1000
Number of cars served	878	934
Average delay (in sec)	118	92

4.0 Conclusion

In this paper, the traffic model and traffic controller are developed using MATLAB software. To test the effectiveness of fuzzy controller to control the traffic flow at an isolated intersection, the MATLAB simulation has been done. The comparison of the proposed controller with the fixed-time controller has shown overall, the fuzzy logic controller shows good performance for controlling traffic flow.

As can be seen, the performance of fuzzy traffic controller is better than fixed-time controller in terms of average number of cars waiting, total departure, and average delay. Each of these features give a positive improvement which indicates that fuzzy logic controllers are better suited in controlling traffic than fixed-time controllers. The fuzzy logic controller model can be modified to suit any intersection by varying the input membership functions which further increases the suitability of this traffic control system.

References

Zhang, L., Honglong, L. and Panos, D. (2004). Signal Control for Oversaturated Intersections using Fuzzy Logic, submitted for consideration for presentation at the 2005 Annual meeting of TRB, Honolulu, Hawaii.

Pappis, C. P, and Mamdani, E. H. (1977). A Fuzzy Logic Controller for a Traffic Junction, IEEE Transactions on Systems, Man, and Cybernetics, Vol. SMC-7, No. 10, October 1977, pp. 707-717.

Chiu, S. I.(1992). Fuzzy Logic Traffic Signal Control System, United States Patent, Patent Number 5,357,436, Thousand Oaks, Calif.

Niittymäki, J. and Pursula, M. (2000). Signal Control using Fuzzy Logic*, Fuzzy Sets and Systems*, Vol. **116**, , pp. 11-22.

Niittymäki, J. and Kikuchi, S. (1998). *Application* of Fuzzy Logic to the Control of a Pedestrian Crossing Signal, Transportation Research Record: Journal of the Transportation Research Board No.1651, TRB, National Research Council, Washington, D.C., pp. 30-38.

Niittymäki, J. and Mäenpää M. (2001). The role of Fuzzy Logic Public Transport Priority in Traffic Signal Control, Department of Transportation Engineering Helsinki University of Technology, Finland.

Nair, B. M. and Cai, J. (2007). A Fuzzy Logic Controller for Isolated Intersection with Traffic Abnormality, Proceedings of the 2007 IEEE Intelligent Vehicles Symposium, Turkey, June 13-15, 2007.

Farmy, M. M. (2007). An adaptive Traffic Signaling for Roundabout with Four-Approach Intersections based on Fuzzy Logic, *Journal of Computing and Information Technology* – CIT 15, 2007, 1, pp. 33-45.

Niittymäki, J. (2001*).* Installation and Experiences of Field Testing a Fuzzy Signal Controller, *European Journal of Operation Research*, Vol **131**, pp 273-281.

Sivanandam, S. N., Sumathi S. and S. N. Deepa S. N. (2007). Introduction to Fuzzy Logic Using MATLAB, Springer-Verlag Berlin Heidelberg, Tamil Nadu, India.

Mathworks (2002). Fuzzy Logic Toolbox: User's Guide (V2.1), The Mathworks Inc.

Mathworks (1999). Using SIMULINK: Version 3, The Mathworks Inc.

Mathworks (2009), *SimEvents 3.0*, The Mathworks Inc.

THIN LAYER DRYING CHARACTERISTICS OF AMARANTH GRAINS IN A NATURAL CONVECTION SOLAR TENT DRYER

E. K. Ronoh, C. L. Kanali, J. T. Mailutha, D. Shitanda
Biomechanical and Environmental Engineering Department, College of Engineering and Technology, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: eriqueron2002@yahoo.com

Abstract
This study aimed at determining thin layer drying characteristics of amaranth grains in a natural convention solar dryer. Initially, ttemperature distribution in the dryer was evaluated using nine discrete points spread in two planes (Planes 1 and 2). Planes 1 and 2 were set at 0.75 and 1.5 m above the concrete base of the dryer. The drying characteristics were determined by drying the grains at two levels (Layers 1 and 2) in the dryer. The control treatment involved drying the grains in the open sun. The mean temperatures and standard deviations for Plane 1 ranged from 38.2–38.4^{o}C and 6.8–7.3^{o}C, respectively. The corresponding values for Plane 2 were in the range of 38.8–39.2^{o}C and 6.6–6.9^{o}C, respectively. At 5% level of significance, there was no significant difference in temperature distribution within and between the planes. Further, the grains dried in the dryer attained an equilibrium moisture content of 7% d.b from an initial value ranging from 61.3–66.7% d.b after 4.5 hours of drying as opposed to 7 hours for the open sun. The effective moisture diffusivity of the grains ranged from 5.49×10^{-12}–6.20×10^{-12} m^2/s. The findings demonstrate the potential of natural convection solar tent dryers in enhancing drying of amaranth grains in vertical layers.

Key words: Solar tent dryer, thin layer, amaranth grains, temperature, moisture diffusivity

1.0 Introduction

Drying is defined as the removal of moisture from a product, and in most practical situations the main stage during drying is the internal mass transfer. Drying is one of the cheap and common preservation methods for biological products (Shitanda and Wanjala, 2003). Successful drying depends on: enough heat to draw out moisture, without cooking the grain; dry air to absorb the released moisture; and adequate air circulation to carry off the moisture. When drying grains, the key factor is to remove moisture as quickly as possible at a temperature that does not seriously affect the flavour, texture and colour of the grain. If the temperature is too low in the beginning, microorganisms may grow before the grain is adequately dried (Vizcarra Mendoza *et al.*, 2003).

Amaranths are drought-tolerant crops and are susceptible to partial shatter losses especially when harvested at a moisture content less than 30% dry basis (d.b) (Prim, 2003; Gupta, 1986). Harvesting of amaranth grains must be done at moisture content of 30% d.b or higher which requires necessary artificial drying to safe storage moisture level. Storage of grain at a moisture content that is higher than the equilibrium moisture level of about 10% d.b leads to mould growth and the grains become unfit for human consumption (Abalone *et al.*, 2006). To ensure safe preservation of amaranth grains, they must be dried to equilibrium moisture content which requires good drying techniques. These grains are mostly dried in the rural areas in thin layers either in the open sun or in a solar dryer (Abalone *et al.*, 2006). Thin layer drying is the process of removal of moisture from a porous media by evaporation, in which drying air is passed through a thin layer of the material until the equilibrium moisture content is reached (Omid *et al.*, 2006).

The open sun drying method has disadvantages such as lack of temperature control, intensive labour and contamination from dust, foreign materials, rodents and bird droppings (Basunia and Abe, 2001). The best alternative, especially when amaranth is produced on commercial basis, is to provide affordable drying methods such as a natural convection solar tent dryer. This type of solar dryer is affordable in the rural set-up, saves labour, ensures good quality of material being dried and facilitates faster drying of grains especially under favourable conditions (Whitfield, 2000). The present work aimed at analyzing thin layer drying characteristics of amaranth grains in a natural convection solar tent dryer. The specific objectives were to analyze the distribution of temperature in the solar tent dryer, and to determine the thin layer drying characteristics of amaranth grains in the solar tent dryer.

2.0 Theoretical Considerations

2.1 Theory of Solar Drying

Solar drying is a form of convective drying, in which the air is heated by solar energy in a solar collector. Solar energy is an important and economical source of renewable energy, particularly during energy crises, when the costs of fossil fuel and electricity increase (Saravacos and Kostaropoulos, 2002). The amount of solar energy reaching the earth's surface is expressed in terms of the solar constant I_{sc}. The I_{sc} is valued at 1367 W/m^2 and is the quantity of energy received from the sun per unit area in a unit time on the earth's surface perpendicular to the sun's rays at a mean distance (1.496×10^8 km) of the earth from the sun (Sukhatme, 2003). Due to the elliptical orbiting of the earth around the sun, the distance between the earth and the sun fluctuates annually and this makes the amount of energy received on the earth's surface to fluctuate in a manner given by Equation 1 where, $I_{sc}^{'}$ is the solar energy flux on the earth's surface at the nth day of the year, n is 1 on 1st January, and 366 on 31st December.

$$I_{sc}^{'} = I_{sc} * \left(1+0.033\cos\left(\frac{360n}{365}\right)\right) \quad \text{.....(1)}$$

The direct solar radiation, I_b, reaching a unit area of a horizontal surface on the earth in the absence of the atmosphere can be expressed by Equation 2 (Sukhatme, 2003). In this equation, $I_{sc}^{'}$ is

solar energy flux on the earth's surface at the n^{th} day of the year (W/m^2), ϕ is latitude (degrees), δ is angle of declination (degrees), ω is hour angle (degrees), and β is angle of inclination of the surface from horizontal surface of the earth.

$$I_b = I'_{sc}\left(\sin(\varphi\text{-}\beta)\sin\delta + \cos\delta\cos\omega\cos(\varphi\text{-}\beta)\right) \quad \text{.....(2)}$$

The angle δ can be evaluated from the expression presented in Equation 3. On the other hand, ω is computed by Equation 4 (Sukhatme, 2003), where H_r is the hour of the day in 24 hour time.

$$\delta = 23.45\sin\left(360\left(\frac{284+n}{365}\right)\right) \quad \text{.....(3)}$$

$$\omega = 15(12 - H_r) \quad \text{.....(4)}$$

The diffuse radiation, I_d, is that portion of solar radiation that is scattered downwards by the molecules in the atmosphere. During clear days, the magnitude of I_d is about 10 to 14% of the solar radiation received at the earth's surface. I_d can be estimated as direct radiation incident at 60^o on the collector surface by Equation 5 (Sukhatme, 2003), where C is the diffuse radiation factor. The total solar radiation, I_t, incident on the horizontal surface such as the collector plate of a solar dryer is therefore obtained by adding the direct and diffuse components of solar radiation as shown in Equation 6. The total solar radiation is of great importance for solar dryers since it captures the required components of solar energy that is harnessed in the dryer.

$$I_d = CI_b\cos 60^0 = 0.5CI_b \quad \text{.....(5)}$$

$$I_t = I_b(1+0.5C) \quad \text{.....(6)}$$

The total solar radiation harnessed by the dryer provides the heat energy incident on the collector surface, Q_i, which is necessary for the drying process. This heat energy is expressed in Equation 7, where A is the area of the energy collector (m^2) and τ is the transmissivity of the collector material.

$$Q_i = I_t A\tau \quad \text{.....(7)}$$

2.2 Moisture Transfer under Thin Layer Drying

The theoretical equations of moisture transfer in grains are transient in nature and their solutions are not easy. Several approaches, including separating the moisture transfer equations for moisture movement in and around the grain, have been suggested. The equation for thin layer drying of grains is given by Equation 8 as reported by Brooker *et al.* (1992). In this equation, M is the moisture content (% d.b) at drying time *t* (hours), M_e is the equilibrium moisture content (% d.b), *k* is the drying rate constant (h^{-1}) and M = M_o (initial moisture content, % d.b) at *t* = 0. Integration of Equation 8 with constant of integration equal to unity yields Equation 9 (Lahsasni *et al.*, 2004).

$$\frac{\partial M}{\partial t} = k\,(M - M_e) \quad \text{..... (8)}$$

$$\frac{M - M_e}{M_o - M_e} = e^{-kt} \quad \text{(for } t > 0\text{) .....} \quad \text{(9)}$$

The ratio on the left hand side of Equation 9 is referred to as moisture ratio (MR). During solar drying, the values of M_e are relatively small compared to M and M_o. In addition, the relative humidity of the drying air varies continuously. Therefore, Equation 9 can be simplified to Equation 10 (Uluko *et al.*, 2006).

$$MR = \frac{M}{M_o} = e^{-kt} \quad \text{..... (10)}$$

Another important parameter that should be considered during drying is diffusivity which is used to indicate the flow of moisture out of the material being dried (Vizcarra-Mendoza *et al.*, 2003).

Therefore, it is important that this parameter is established during drying of grains such as amaranth. In the falling rate period of drying, moisture is transferred mainly by molecular diffusion. Moisture diffusivity is influenced mainly by moisture content and temperature of the material. For a drying process in which the absence of a constant rate is observed, the drying rate is limited by the diffusion of moisture from the inside to the surface layer, represented by Fick's law of diffusion (Crank, 1975). Assuming that amaranth grains can be approximated to spheres, the diffusion is expressed by Equation 11 (Konishi *et al*., 2001), where D_e is the effective moisture diffusivity (m^2/s) and r_a is the radius (≈0.0005 m) of amaranth grain.

$$\frac{\partial M}{\partial t} = D_e\left(\frac{\partial^2 M}{\partial r_a^{\,2}}\right) \quad \text{..... (11)}$$

For the transient diffusion in a sphere, assuming uniform initial moisture content and a constant effective diffusivity throughout the sample, the analytical solution of Equation 11 yields Equation 12.

$$MR = \frac{M-M_e}{M_o-M_e} = \left(\frac{6}{\pi^2}\right)\exp\left[-D_e t\left(\frac{\pi^2}{r_a^{\,2}}\right)\right] \quad \text{..... (12)}$$

The effective moisture diffusivity is determined by applying logarithms to Equation 12 to obtain a linear relation of the form shown in Equation 13. Therefore, a plot of ln(MR) versus time yields a straight line, and the diffusivity is determined from the slope (slope = $-D_e\pi^2/r_a^{\,2}$).

$$\ln(MR) = \ln\left(\frac{6}{\pi^2}\right) - \left(D_e\frac{\pi^2}{r_a^{\,2}}\right)t \quad \text{..... (13)}$$

3.0 Materials and Methods

3.1 Description of the Solar Tent Dryer

Figure 1 shows the schematic diagram of the natural convection solar tent dryer used in this study. The dryer consisted of a chimney, the main structure with a door and a concrete base. The main structure measured 1.85 m wide, 2.73 m long and 2.55 m high. The top part of this structure is semi-circular in shape with a radius of 0.5 m and the entire structure is covered with a polyvinyl chloride (PVC) material. The PVC material is preferred because it filters radiations such as ultraviolet, which can destroy light sensitive nutrients in the material being dried (Leon *et al*., 2002). The chimney measuring 0.2 m long, 0.2 m wide and 0.4 m high is provided at the top center of the dryer to enhance natural convective air circulation. The dimensions of the door are 0.6 m wide and 1.8 m high. The solar tent dryer was placed on a concrete base measuring 1.95 m wide, 2.83 m long and 0.075 m high. The concrete base was provided in order to collect grains easily in case of spillage, to concentrate heat harnessed in the dryer, and to avoid water draining into the dryer.

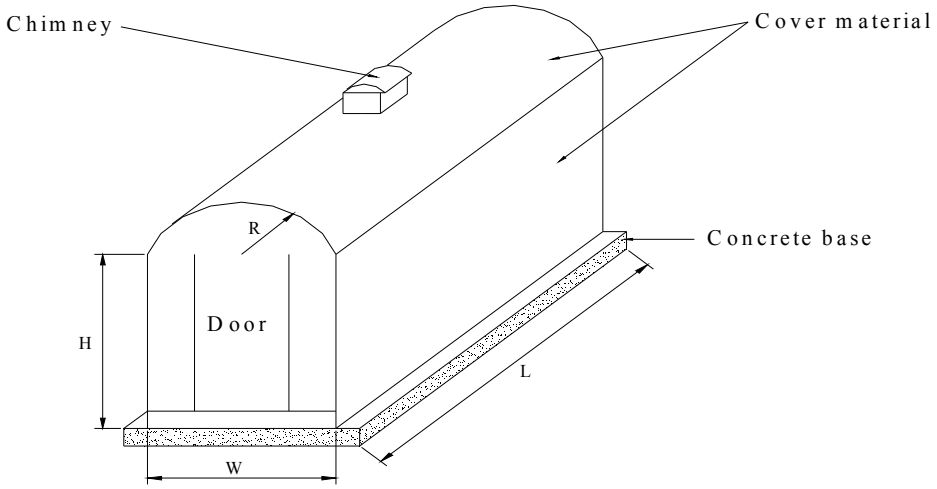


Figure 1: Schematic of the natural convection solar tent dryer. In this figure: W = 1.85 m; L = 2.73 m; H = 2.05 m; R = 0.5 m

3.2 Analyzing the Distribution of Temperature in the Solar Tent Dryer

Prior to determining the thin layer drying characteristics of amaranth grains, it was necessary to monitor how temperature were distributed in the dryer. Traditionally, grains are dried in solar dryers in single layers (Basunia and Abe, 2001). The need for enhancing output and efficiency, and for minimizing cost requires that grains be dried in a series of layers. To determine the suitable positions of these layers, it is necessary that the temperature distribution in the solar tent dryer be evaluated. In this study, the evaluation was carried out by monitoring temperatures at different locations in the x,y,z-plane in the dryer, the origin being the centre of the ground surface inside the solar tent dryer. The positions for recording temperature distribution were defined by discrete points (x_i,y_j,z_i) as shown in Figure 2, on which m_1 vertical lines, n_1 lateral lines and p_1 horizontal lines were distributed. The discrete points were located at intersections of the lines and the coordinates were established from Equations 14–16. In these equations, W, L and H are the width, length and height of the main structure (Figure 1), respectively.

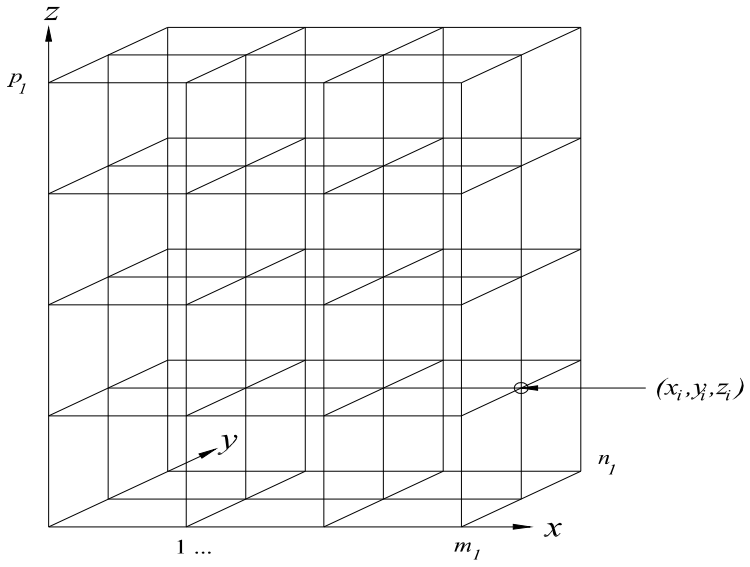


Figure 2: Discretization of temperature distribution points in the solar tent dryer

$$x_i = (i-1)\left.\frac{\mathrm{W}}{(m_1-1)}\right|_{i=1\ to\ m_1} \quad \text{..... (14)}$$

$$y_i = (j-1)\left.\frac{\mathrm{L}}{(n_1-1)}\right|_{j=1\ to\ n_1}$$

.....(15)

$$z_i = (l-1)\left.\frac{\mathrm{H}}{(p_1-1)}\right|_{l=1\ to\ p_1} \quad \text{.....(16)}$$

Figure 3 shows two planes (Planes 1 and 2) in the solar tent dryer on which nine discrete points on each plane were located for monitoring temperature distribution. These points were defined in such a way that Plane 1 was considered to be in the positive x-direction and at a vertical distance of 0.75 m from the ground surface (z = 0.75 m). Plane 2 was set at 0.75 m higher from the Plane 1 (z = 1.5 m) to avoid shading and enhance air circulation. The spacing between the concrete base and Plane 1, and between Planes 1 and 2 of 0.75 m were subjectively set. The points along the two planes constituted the y coordinates.

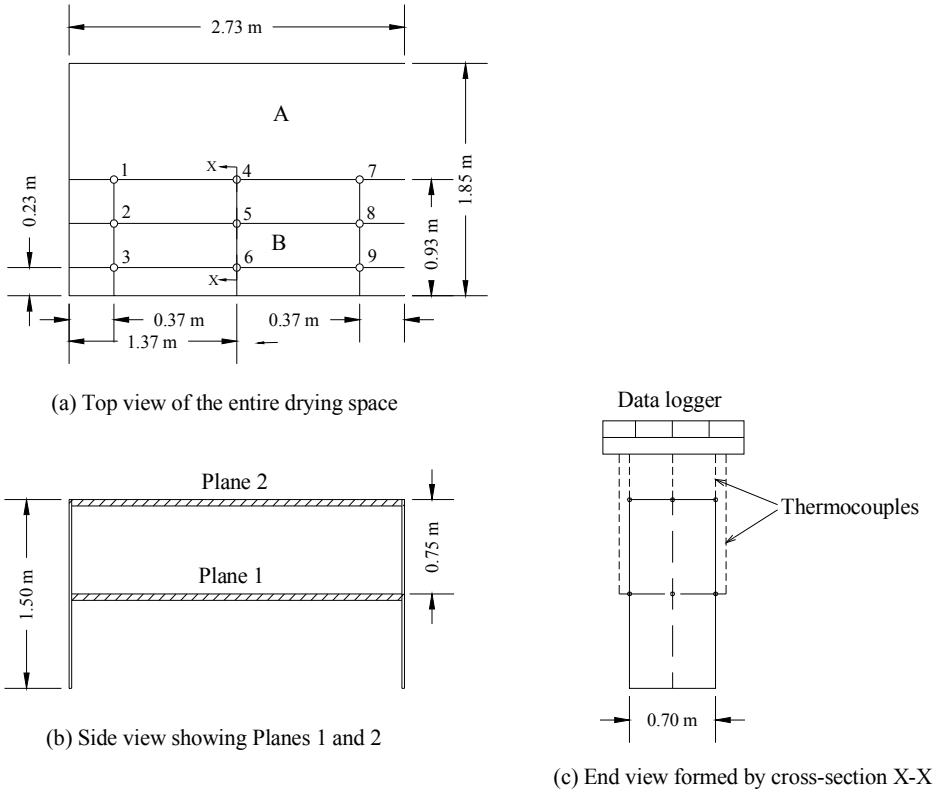


Figure 3: Schematic of temperature distribution acquisition system in the solar tent dryer

Temperature data were recorded using thermocouples which relayed the information to a Thermodac electronic data logger (ETO Denki E, Japan) with ±1^{o}C accuracy. The data were acquired for three consecutive days for 10 hours on each day at intervals of one hour starting from 8:00 a.m. Preliminary tests conducted on temperature distribution in Sections A and B (see Figure 3(a)) established that the temperatures in the two sections were not significantly different. Hence, in this

study temperatures were monitored only in Section B of the solar tent dryer. Analysis of variance (ANOVA) was conducted on the data using GenStat (Discovery Edition 3) statistical tool to determine whether or not there existed significant difference for temperature distribution within the same plane and between planes.

3.3 Determining the Thin Layer Drying Characteristics of Amaranth Grains

Two layers of drying trays were arranged in the dryer, each layer measuring 0.5 m wide, 2.45 m long and 0.75 m high as shown in Figure 4. Layer 1 is raised 0.75 m above the concrete surface while Layer 2 is at a height of 1.5 m. Flat and angled iron bars were used to fabricate these trays, and a fine wire mesh fixed at the top of each layer on which the grains were placed.

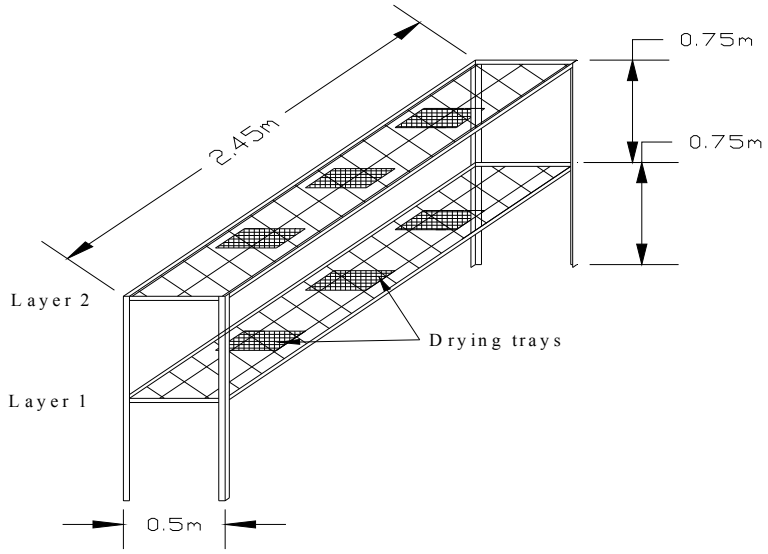


Figure 4: Schematic diagram showing the arrangement of drying trays in two layers

Data acquisition involved recording temperature and relative humidity values, and monitoring moisture content of the grains during drying in the solar tent dryer and the open sun. The data were recorded at 30 minutes intervals from 9:00 a.m to 4:00 p.m for three consecutive days. In order to determine the moisture content, grain samples were weighed in a drying dish of known weight and the wet weight recorded as W_t. The capacity and sensitivity of Shimadzu electronic balance (LIBROR EB-4300D, Japan) used were 600g and 0.01g, respectively. The samples were placed in a constant-temperature oven set at a temperature of 105^{o}C for about 24 hours. The dried grains were removed from the oven and the dry weight, W_d, recorded. The percent dry basis moisture content M was then evaluated from the expression (Bala, 1997) given by Equation 17.

$$M = \frac{W_t - W_d}{W_d} * 100 \quad \text{..... (17)}$$

4.0 Results and Discussion

4.1 Temperature Distribution in the Solar Tent Dryer

The analysis of temperature distribution in the solar tent dryer was conducted on two planes (viz., Planes 1 and 2 as shown in Figure 4). Planes 1 and 2 are located at 0.75 and 1.5 m above the concrete base. Nine identical discrete points on each plane were utilized for monitoring the temperature. A total of 90 daily temperature data were obtained for each plane.

Results of the mean temperature distribution for Planes 1 and 2 are shown in Table 1. As seen from the table, the mean temperatures and standard deviations for Plane 1 ranged from 38.2–

38.4°C and 6.8–7.3°C, respectively. The corresponding values for Plane 2 ranged from 38.8–39.2°C and 6.6–6.9°C, respectively. This shows that there was less variation in the temperature distribution within the planes. However, the temperatures for Plane 2 were slightly higher than those of Plane 1. This is because Plane 2 was closer to the solar energy collector surface. An ANOVA conducted at 5% level of significance shows that there was no significant difference in temperature distribution within Plane 1 (p-value, 0.999; $F_{critical}$, 2.055; $F_{computed}$, 0.002) and Plane 2 (p-value, 0.999; $F_{critical,}$ 2.055; $F_{computed}$, 0.007) as the $F_{computed}$ values were lower than the $F_{critical}$ ones.

Table 1: Distribution of mean temperatures in the solar tent dryer

Temperatures (°C) developed at different discrete points in the solar tent dryer									
	(a) Discrete points in Plane 1								
	1	2	3	4	5	6	7	8	9
Mean	38.2	38.4	38.3	38.2	38.4	38.3	38.2	38.4	38.3
Stdev	7.3	7.3	7.2	7.0	7.2	6.8	6.9	7.0	7.1
	(b) Discrete points in Plane 2								
	10	11	12	13	14	15	16	17	18
Mean	39.1	39.2	38.8	39.2	38.9	39.2	38.9	39.2	38.8
Stdev	6.9	6.7	6.8	6.7	6.8	6.8	6.8	6.6	6.7

Similarly, there was no significant difference in temperature distribution between the planes as the $F_{computed}$ was less than the $F_{critical}$ (p-value, 0.813; $F_{critical}$, 4.414; $F_{computed}$, 0.058). The above findings imply that one can achieve uniform drying of agricultural produce when drying in thin layers on any plane in the solar tent dryer. These results are in agreement with the observations reported by Mwithiga and Kigo (2006) in studying the temperature distribution in a solar dryer with limited sun tracking capability under similar conditions. Further, the results show that the dryer output can be doubled at minimal cost by drying the produce on two vertical layers in the solar tent dryer without compromising on the drying efficiency. However, when drying on different layers shading should be avoided and the spacing between the planes should be such that air circulation is not inhibited.

4.2 Thin Layer Drying Characteristics of Amaranth Grains in the Solar Tent Dryer

The drying characteristics of amaranth grains evaluated in this study comprised moisture content and effective moisture diffusivity. In order to determine these characteristics, temperature and moisture content data were acquired within the dryer at two levels (i.e., Layer 1 and Layer 2 as shown in Figure 4). Figure 5 compares the temperatures developed in the solar tent dryer and the open sun. It is seen from the figure that the temperatures in the dryer (44.2 ± 6.4°C) were higher than those in the open sun (27.8 ± 2.6°C) over the entire drying period. In addition, temperatures developed in Layer 2 were always higher (48.9±4.8°C) than those in Layer 1 (39.5 ± 3.8°C). This is due to the fact that Layer 2 was closer to the solar energy harnessing surface than Layer 1. Figure 5 also shows that increase in solar radiation led to increase in temperature, indicating a direct relationship between solar radiation and temperature developed both in the dryer and the open sun.

Further comparison of temperatures developed in the dryer and the open sun during drying of amaranth grains was done using ANOVA at 5% level of significance. The results show that there was significant difference (p-value, 2.44 x 10^{-06}; $F_{critical}$, 4.196; $F_{computed}$, 34.737) between temperatures developed in Layers 1 and 2. There seem to be a contradiction between the preceding results and those obtained in Section 5.1 that dealt with distribution of temperature in the dryer without drying the grains. The earlier results, unlike the current ones, showed no significant difference in temperatures between Layers 1 and 2. When grains were spread on Layer 2, they caused shading on Layer 1 and this may have resulted in significant lowering of temperatures on this layer. Similarly, the results show that there was significant difference (p-value, 1.26x10^{-17}; $F_{critical}$, 3.220; $F_{computed}$,

112.963) between temperatures developed in the dryer and the open sun. This further confirms that solar tent dryers can effectively be used to harness solar energy for drying of agricultural products (Sacilik *et al*., 2006; Abalone *et al*., 2006)] such as amaranth grains.

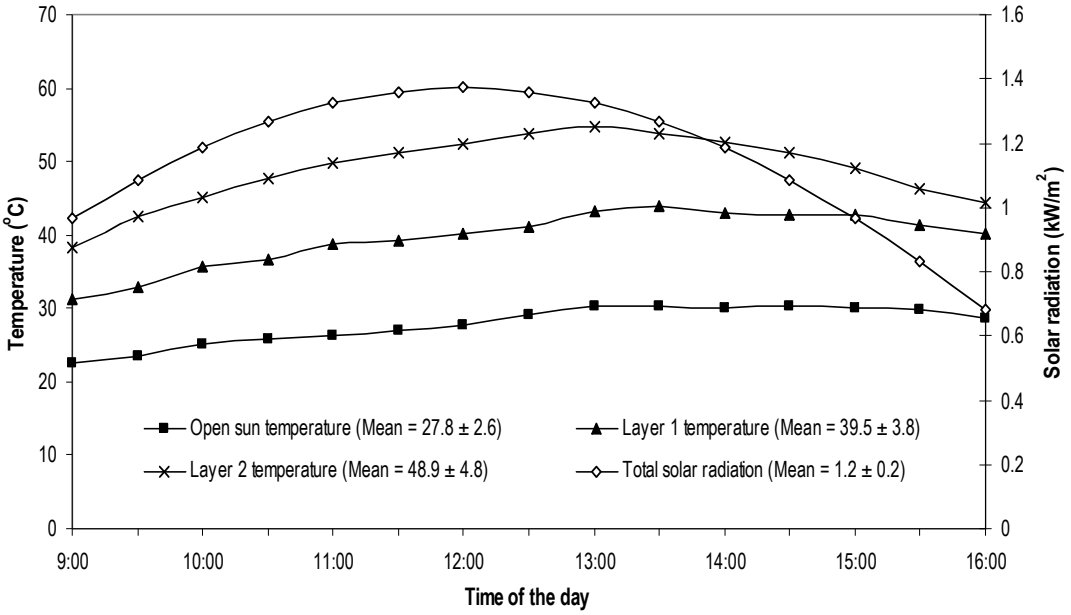


Figure 5: Comparison of temperature and total solar radiation with drying time in the solar tent dryer and the open sun

Figure 6 presents the relative humidity values recorded in the solar tent dryer and the open sun. The relative humidity values in the dryer were always lower (25.6 ± 4.3%) than those in the open sun (29.5 ± 5.4%) during the drying period. An ANOVA conducted on the results showed no significant difference between the relative humidity values for the dryer and the open sun (*p*-value, 0.039; $F_{critical}$, 3.220; $F_{computed}$, 3.497). The results obeyed the commonly observed behaviour that relative humidity decreases with increase in temperature (Basunia and Abe, 2001).

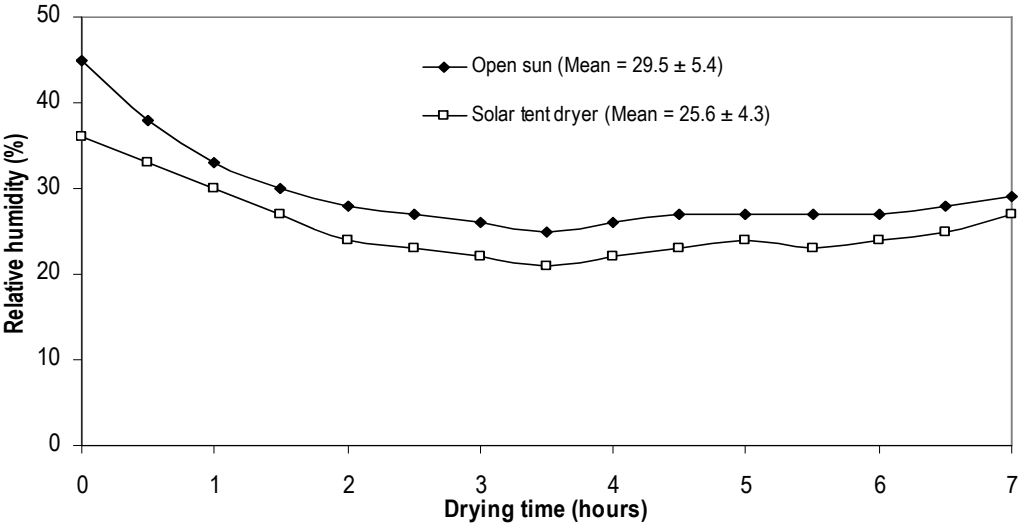


Figure 6: Comparison of relative humidity in the solar tent dryer and the open sun during drying of amaranth grains.

Regression analyses relating the temperature (T_i) and relative humidity (Rh_i) inside the solar tent dryer to the open sun temperature (T_a) and relative humidity (Rh_a), and total solar radiation (I_t) yielded linear relationships as shown in Equations 18 and 19. The high R^2 values (>0.95) obtained imply that there is a strong correlation between the drying conditions inside the solar tent dryer and the open sun conditions.

$T_i = 1.38T_a + 14.66I_t - 6.27 \quad R^2 = 0.99$.....(18)

$Rh_i = 0.74Rh_a - 2.62I_t + 6.63 \quad R^2 = 0.96$.....(19)

The drying curves of amaranth grains in Layers 1 and 2 of the solar tent dryer and the open sun are shown in Figure 7. The figure shows that the moisture content decreased continuously with increase in time. Many researchers (Basunia and Abe, 2001; Abalone *et al.*, 2005; Omid *et al.*, 2006) have noted the same observation, particularly, for cereal grains. The results show that under all the three drying conditions (viz., open sun, Layer 1 and Layer 2) the rate of drying was highest within the first 2.5 hours of drying. The drying rate reduced significantly for the subsequent hours of drying. Further, the results show that amaranth grains with initial moisture content ranging from 61.3–66.7% d.b dried to an equilibrium moisture content of 7% d.b. It took 3.5, 4.5 and 6 hours to attain the equilibrium moisture content for Layer 2, Layer 1 and open sun, respectively. It is also shown by the drying curves that the entire thin layer drying process of amaranth grains obeyed the falling rate period (Diamente and Munro, 1993).

When Layers 1 and 2 are compared, it is noticed that the drying rate was higher for the latter than the former at any given time (Figure 7). This is because Layer 2 attained high drying temperatures as compared to Layer 1. Similarly, comparison of the solar dryer and the open sun shows that the drying rate was high for the dryer. The temperatures recorded in the dryer were higher than those in the open sun. In addition, the relative humidity values were lower in the dryer than in the open sun. The higher the temperature and the lower the relative humidity, the faster the drying (Ronoh *et al.*, 2009; Sacilik *et al.*, 2006).

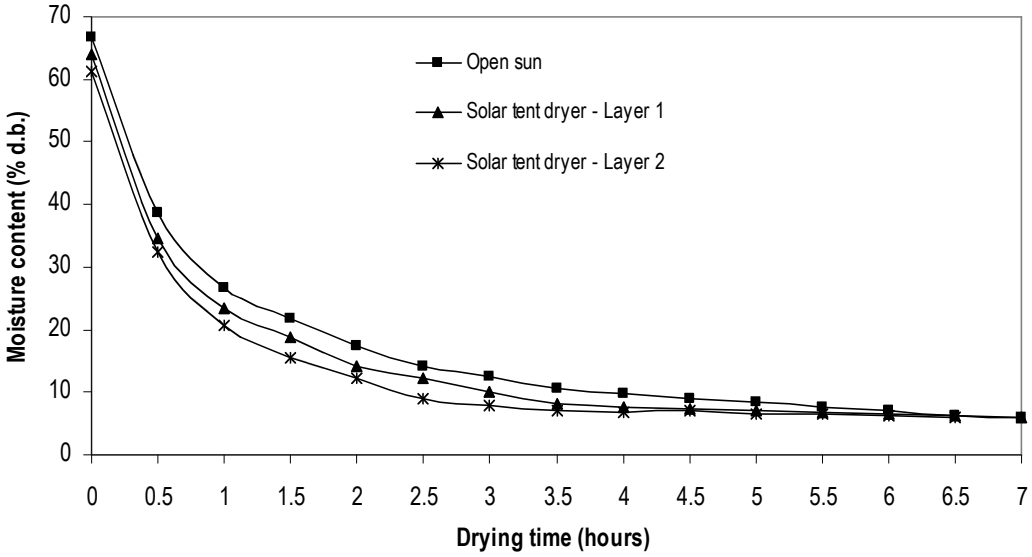


Figure 7: Drying curves for amaranth grains dried under open sun and in the solar tent dryer

An ANOVA conducted on the drying data at 5% level of significance shows that for the first 2.5 hours of drying the drying rates were not significantly different under the solar dryer and the open sun (*p*-

value, 0.881; $F_{critical}$, 3.682; $F_{computed}$, 0.127). During this drying period there is sufficient energy and relative humidity to dry the grains under both conditions, a characteristic of the first falling rate drying period (Omid *et al*., 2006). Conversely, the drying rates for the solar dryer and the open sun were slightly different between 2.5–8 hours of drying since the $F_{critical}$ obtained was lower than the $F_{computed}$ (*p*-value, 0.033; $F_{critical}$, 3.403; $F_{computed}$, 3.934). The slight difference can be attributed to the difference in energy and humidity levels recorded under both drying conditions. When the drying rates for Layer 1, Layer 2 and the open sun are compared for the entire drying period, the results show that there was no significant difference among them (*p*-value, 0.837; $F_{critical}$, 3.220; $F_{computed}$, 0.179). Although the preceding findings imply that there is no need for employing a solar tent dryer vis-a-vis the open sun for drying amaranth grains, extra energy and favourable relative humidity conditions are required to dry the grains to equilibrium moisture content. This extra energy and conducive relative humidity can sufficiently be provided by the solar tent dryer as opposed to the open sun. Similar observations have been noted by Basunia and Abe (2001) during thin layer drying of rough rice under natural convection.

Comparison of the drying rates on Layers 1 and 2 of the solar dryer within the first 2.5 hours of drying shows no significant difference (*p*-value, 0.819; $F_{critical}$, 4.965; $F_{computed}$, 0.055). Similarly, the results show no significant difference (*p*-value, 0.2017; $F_{critical}$, 4.494; $F_{computed}$, 1.776) in the drying rates between 2.5–8 hours of drying on Layers 1 and 2. These results, therefore, show that Layers 1 and 2 of the solar tent dryer can be used to dry amaranth grains in thin layers without significantly affecting the drying rate of the grains.

Moisture transfer in amaranth grains during the thin layer drying process can be explained by the effective moisture diffusivity (D_e). Figure 8 shows a semi-logarithmic plot of dimensionless moisture ratio versus time in the solar tent dryer and the open sun. The slope of this plot was taken for the computation of D_e using Equation 13. The D_e values of amaranth grains attained for Layers 1 and 2 were 5.88×10^{-12} and 6.20×10^{-12} m^2/s, respectively, while for the open sun the value was 5.49×10^{-12} m^2/s. The diffusivity values obtained are of the same order of magnitude as those reported for amaranth grain (Vizcarra Mendoza *et al.*, 2003). The effective moisture diffusivities calculated from the drying data represented an overall mass transport property of moisture in the grains. High temperatures developed on Layer 2 of the solar tent dryer led to highest D_e value and this clearly shows a dependence of moisture removal from amaranth grains on temperature.

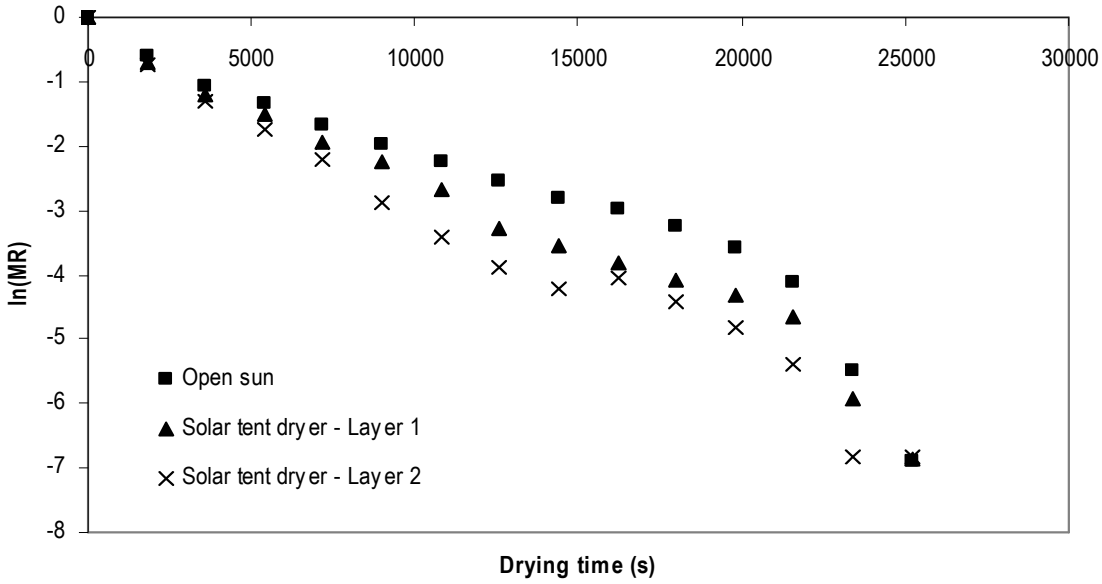


Figure 8: Variation of ln(MR) with drying time in the solar tent dryer and the open sun

5.0 Conclusions and Recommendations

The results of this study show that there was no significant difference in the distribution of temperature within and between Planes 1 and 2 that were spaced at 0.75 and 1.5 m above the ground concrete surface of the solar tent dryer, respectively. This implies that the dryer capacity can be increased by drying the grains in layers. However, high mean temperatures in the range of 38.8–39.2^{o}C were developed at Plane 2 as compared to 38.2–38.4^{o}C for Plane 1. In addition, the results indicate that the solar tent dryer successfully dried amaranth grains to an equilibrium moisture content of 7% d.b after 4.5 hours of drying as opposed to 7 hours for the open sun. The findings demonstrate that the dryer output can be increased by drying the grains in vertical layers without significantly affecting the drying rate. Since the vertical spacing was subjectively chosen, there is need to determine whether or not more layers can be utilized to achieve effective drying of agricultural produce in the solar tent dryer under natural convection.

Acknowledgement

The authors sincerely express their appreciation to Jomo Kenyatta University of Agriculture and Technology (JKUAT) for their financial support and research facilities offered to carry out this study.

References

Abalone, R., Cassinera, A., Gastón, A. and Lara, M. A. (2006). Thin layer drying of amaranth seeds. *Biosystems Engineering*. **93**(2), pp 179–188.

Bala, B. K. (1997). *Drying and storage of cereal grains*. Science Publishers, Inc. Plymouth, UK.

Basunia, M. A. and Abe, T. (2001). Thin-layer solar drying characteristics of rough rice under natural convection. *Journal of Food Engineering*, **47**(4), pp 295–301.

Brooker, C. W., Bakker-Arkema, F. W. and Hall, C. W. (1992). Drying and storage of grains and oilseeds. Van Nostrand Reinhold, New York, USA.

Crank, J. (1975). *Mathematics of diffusion* (2nd Ed.). London: Oxford University Press.

Diamente, L. M. and Munro, P. A. (1993). Mathematical modelling of the thin layer solar drying of sweet potato slices. *Solar Energy*. pp. 271–276.

Gupta, V. K. (1986). Grain amaranths in Kenya. **In**: Proc. Third Amaranth Conf. Rodale Press, Inc., Emmaus, Pennsylvania.

Konishi, Y., Horiuchi, J. I. and Kobayashi, M. (2001). Dynamic evaluation of the dehydration response curves of food characterized by a poultice-up process using a fish-paste sausage: A new tank model for computer simulation. *Drying Technology*. **19**(7), pp 1271–1285.

Lahsasni, S., Kouhila, M., Mahrouz, M., Idlimam, A. and Jamali, A. (2004). Thin layer convective solar drying and mathematical modeling of prickly pear peel (*Opuntia ficus indica*). *Energy*. **29**(2), pp 235–249.

Leon, M. A., Kumar, S. and Bhattacharya, S. C. (2002). A comprehensive procedure for performance evaluation of solar food dryers. *Renewable and Sustainable Energy Reviews*, **6**(4), pp 367–393.

Mwithiga, G. and Kigo, S. N. (2006). Performance of a solar dryer with limited sun tracking capability. *Journal of Food Engineering*, **74**, pp 247–252.

Omid, M., Yadollahinia, A. R. and Rafiee, S. (2006). A thin-layer drying model for paddy dryer. Proceedings of the International conference on Innovations in Food and Bioprocess Technologies. 12th–14th December 2006, AIT, Pathumthani, Thailand.

Prim, L. (2003). Growing and harvesting quinoa and amaranth. Newsletter #38: Seeds of Change, 29th November 2003.

Ronoh, E. K., Kanali C. L., Mailutha J. T. and Shitanda D. (2009). Modeling thin layer drying of amaranth seeds under open sun and natural convection solar tent dryer. *Agricultural Engineering International: the CIGR Ejournal*. Manuscript 1420. Vol. XI. November, 2009.

Sacilik, K., Keskin, R. and Elicin, A. K. (2006) Mathematical modeling of solar tunnel drying of thin layer organic tomato. *Journal of Food Engineering*, **73**, pp 231–238.

Saravacos, G. D. and Kostaropoulos, A. E. (2002). Handbook of food processing equipment. Kluwer Academic/Plenum Publishers, New York.

Shitanda, D. and Wanjala, N. V. (2003). Effect of different drying methods on the quality of jute (*Corchorus olitorius L.*). *Proceeding of the 3rd Asian-Pacific Drying Conference*. Asian Institute of Technology-Bangkok, Thailand. 1st–3rd September, pp. 627–636.

Sukhatme, P. K. (2003). Solar energy: principles of thermal collection and storage. 2nd Ed., Tata McGraw-Hill Publishing, New Delhi.

Uluk, H., Kanali, C. L., Mailutha, J. T. and Shitanda, D. (2006). A finite element model for the analysis of temperature and moisture distribution in a solar grain dryer. *The Kenya Journal of Mechanical Engineering*, **2**(1), pp 47–56, Fimen Publishers, Nairobi, Kenya.

Vizcarra-Mendoza, M. G., Martinez, V. C. and Caballero, D. F. (2003). Thermal and moisture diffusion properties of amaranth seeds. *Biosystems Engineering*, **86**(4), pp 441–446.

Whitfield, D. E. (2000). Solar drying. International Conference on Solar Cooking. Kimberly, South Africa, 26th–29th November 2000.

A STUDY OF AN URBAN DOMESTIC COMPOSITE LOAD MODEL SUITABLE FOR SOLAR PV AND GRID HYBRID SYSTEM

G. G. Kidegho[1], M. S. Mbogho[2], M. C. Muriithi[3]
Department of Electrical and Electronic Engineering, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-Mail: kideghogee@eng.jkuat.ac.ke

Abstract
In every power supply system, the load is a major component to the system voltage stability. For this reason, load modeling is done to predict the behavior of the load. The load behavior in a power system directly affects the voltage profile of the system. In most generation systems in a country, the urban domestic load consumes up to 30% of the total generated power. It is with this fact in mind that this paper carried out an urban domestic load modeling to study the effects of disturbances and perturbations caused by the load to a power generation system. In the study, a solar PV and grid hybrid system is used. An equivalent circuit of an induction motor is used as a dynamic load together with the static domestic load to form the load model. The study uses both quantitative and qualitative analysis methods and also explores the use of trajectory sensitivity concepts. Using load analysis software; Excel and MATLAB the load was modeled. The domestic load used in the study is drawn from a study case suburb; Embakasi Nyayo Estate. Preliminary results obtained indicate accurate predictions for the hybrid solar PV and grid system. The investigations further indicate that load voltage dynamics can significantly influence the damping of modal oscillations. Further, as the system becomes more stressed, sensitivity to parameter variations increase significantly and this can be used to predict marginal stable behavior.

Key words: Load modeling, distribution system, voltage profile, urban domestic load

1.0 Introduction

The load is a major component to the stability of the Voltage of any electrical power system. In most electrical systems, the industrial load forms the bulk of the electrical burden. However, the domestic load also forms a considerable proportion of the entire electrical burden in most countries including Kenya as shown by the Kenya weekly load curves on Figure 1. For this reason, load models are done to enable system engineers to predict the undesirable effects of the load variations. Though accurate load models are normally difficult to achieve due to the dynamic nature of loads, the inaccurate models still serve as an indicator to the predictions. With these predictions system engineers are able to prepare to engage control devices to stabilize the system voltages at the affected load centers.

In this paper a domestic urban load from a case study suburb in Nairobi is aggregated and modeled to demonstrate its effects on the power system. It is important to note from the onset that urban domestic load consists of both static and inductive loads like heating and refrigeration appliances respectively. The refrigerators and freezers have a time constant greater than 0.5seconds so they have been modeled as dynamic loads [1].

The domestic load is normally a parallel interconnection of the static and inductive loads in any homestead. These loads are then connected to the electricity supply system depending on domestic activities in a homestead. Results obtained by the on the preliminary studies at the case study, reveal that domestic activities that demand most electrical power occur in the early morning at 7AM and late evening 8.30PM as observed in Figure 1. Some of these domestic loads are electronic appliances which when energized inject harmonics in the system and cause harmonic distortion in the system voltage waveform [2].

Table 1 shows the load/appliance types, power rating and duty cycle of the loads found in most homesteads in the case study.

Table 1: Domestic load

S/N	*Appliance*	*No*	*Watt*	*Duty Cycle*	*Load Type*
1	Cf lamps	10	11	4	Electronic
2	Radio	1	22	2	Electronic
3	TV 21	1	50	8	Electronic
4	Iron	1	1000	4	Static
5	Cooker	1	1000	1	Static
6	Microwave	1	3500	0.5	Electronic
7	Toaster	1	1500	0.5	Static
8	Hair dryer	1	1500	0.5	Inductive
9	Coffee	1	1200	0.5	Static
10	DVD	1	50	0.5	Electronic
11	Computer	1	110	2	Electronic
12	Lap top	1	65	4	Electronic
13	Fridge	1	300	4	Inductive
14	D/ Freezer	1	500	2	Inductive
	Total	**23**	**10808**		

Source: Generated by the study

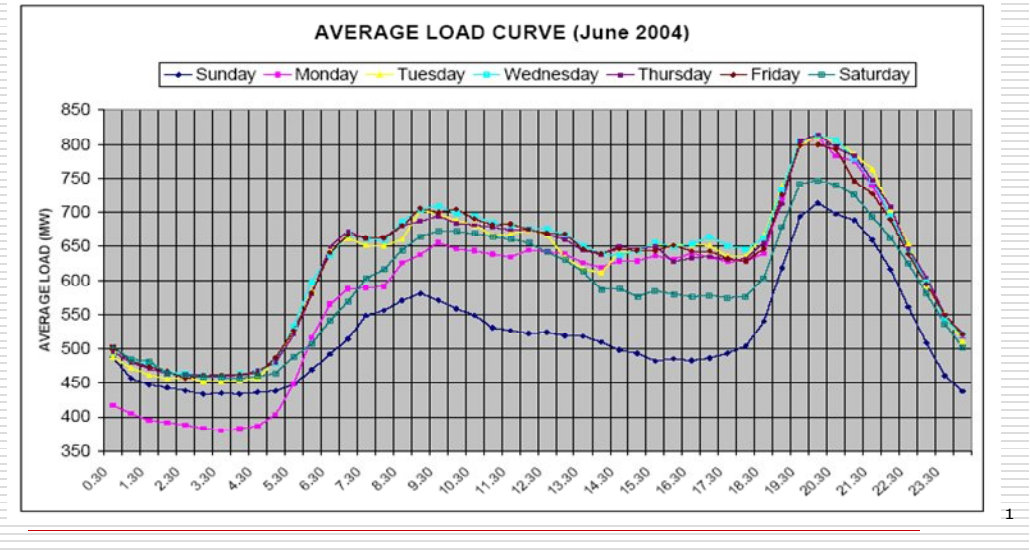
The inductive loads shown above operate at a lagging power factor thereby needing power factor correction attention. On the other hand the resistive loads operate at near unity power factor (0.95lag). When these loads are aggregated, their effect is large enough to require prompt reactive power compensation to avoid voltage collapse at the nearest load bus. Apart from the reactive power demand, these loads demand high current when starting thereby raising the peak demand of the system as shown on the Table 2 and the load curve (2004)[3]. An example is the refrigerator which runs at 300watts at full load but will require 1500watts to start. Figure 1 shows the effects of the domestic load to the national load curve during the domestic peak of 8.30PM. Studies done elsewhere showed that the domestic load contributes up to 30% to some country's national load demand [4].

Table 2: Steady state and surge power

S/N	Type of Load	Power (W)	Surge Power (W)
1	Fridge	300	1500
2	D/Washer	700	1500
3	C/Washer	650	1150
4	D/Freezer	450	1800

Source: Generated by the Study

This national peak is normally supplied by fossil fuel generators which generate expensive energy units. The National peak starts building at 6.30 p. m. and attains its apex at 8.30 p. m. The load peak then starts reducing gradually at 8.30 p. m. when the domestic load is shut down. At 10 p. m. the domestic load is completely shut down leaving only the few industrial and commercial consumers which run 24 hours.



Source: KPLC (2004)

Figure 1: Kenya national weekly load curve

2. 0 Theory and Methodology

The methodology applied in the study was:

( ) To take spot hourly domestic power consumption data and observe the load behavior in MS Excel.

(i) To categorize the static loads and the inductive loads and obtain resistance and inductance values for each.

(ii) Use the obtained data in MATLAB Simulink to simulate and observe the effects to the power supply.

(iii) Use MATLAB to investigate the effects of harmonics to the voltage profile.

(iv) Aggregate the peak demand and observe the effects to the power system.

For the MATLAB Simulink simulation, the split phase single phase motor is used to represent the refrigerator compressor motor and pure resistances are used to represent the heating loads. Below is an induction motor equivalent circuit.

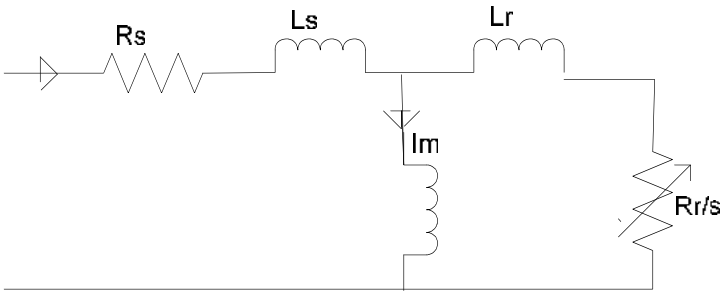


Figure 3: Induction motor equivalent circuit

Rs = Stator resistance, Ls = Stator inductance, Lr = Rotor inductance, Rr/s = Rotor resistance, Im = Magnetizing current.

The typical model used for an individual homestead is a parallel connection of the resistive loads and the inductive loads as shown in Figure 4:

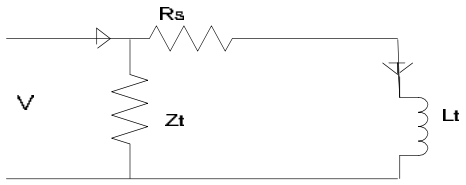
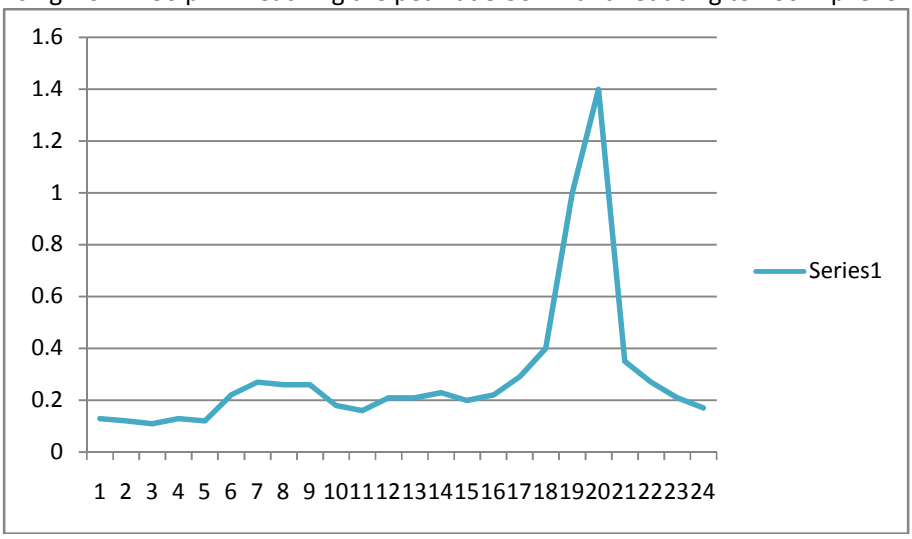


Figure 4: Domestic load model

Zt = Total connected resistive load in the home,
Lt = Total connected inductive load in the home.

3. 0 Results and Discussions

The data collected on spot measurements was used to generate a graphical response. Figure 2 is the curve showing the average hourly power consumption for the case study (Embakasi Nyayo Estate). The peak power consumption occurs at 8.30PM and the power is 1.4 kWp. The power demand starts rising from 7.30 p. m. reaching the peak at 8.30Pm and reducing to 400 Wp level at 9.00 p. m.



Source: Generated by the Study

Figure 2: Average hourly power consumption (kW)

Note that this domestic peak coincides with the national peak observed in Figure 1. This phenomenon supports the argument that the national peak observed at 8.30 p. m. is driven by the domestic load. When this domestic peak power is aggregated in the entire estate of 4774 units [5], the case study estate peak power is 6.683 MW. This is a substantial power demand peak for one urban estate.

Table 3 shows the categorized data that was used in the MATLAB Simulink simulations. These loads were simulated as intermittent load considering domestic activities.

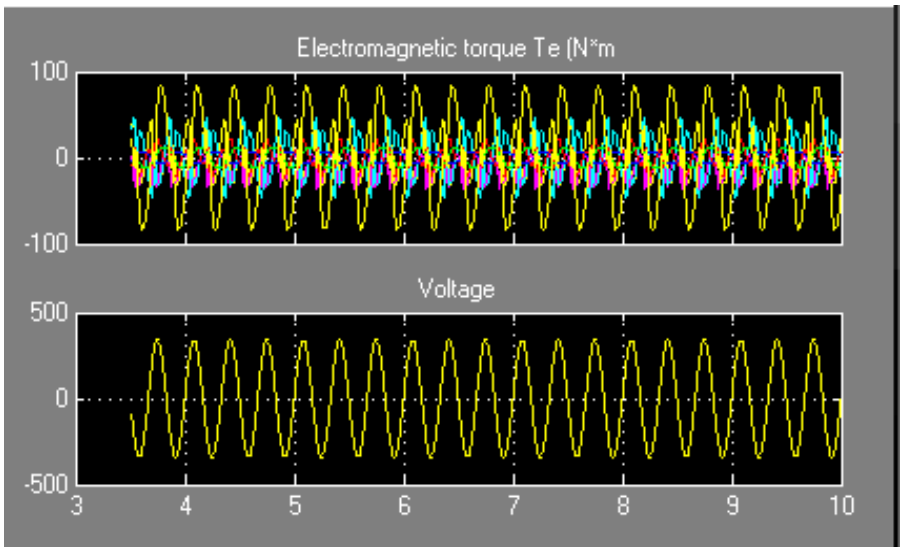
Table 3: Domestic load data that was used

Load	Load Type	Power Rating Watts	Rating in Ohms
1	Resistive (Electric Irons, Electric cooker, Heaters, Toasters)	4700	177.6
2	Electronic (Television, Radio, DVD, Computers and Lap tops, CFC lamps)	297	214.5
3	Inductive (Refrigerators, Freezers, mixers, Blenders, Microwave oven)	4350	Reactance = 89.7 Reactive Q = 3262.5

Source: Generated by the study

Preliminary results obtained reveal that though domestic loads connection to the supply occurs at random; there is more concentration between 7.30 p.m. and 8.30 p. m. when domestic operations are intense. The results also show that the domestic load can be predicted very accurately thereby providing an opportunity to its mitigation or control.

The Simulink simulations results reveal some harmonic distortion of third and second order harmonics which affect the voltage profile adversely [6]. The graph on Figure 3 for the electromagnetic torque developed by the compressor motor shows torque pulsations occurring at 40, 30, 10, 2 Nm.These pulsations reduce the efficiency of the machine thereby requiring more power for the same task. The Voltage profile is smooth when the compressor motor and resistive load are connected to the supply.



Source: Generated by the study

Figure 3: Electromagnetic torque –Nm and voltage

When Simulations were done with the entire domestic load including the electronic devices the graphs on Figure 4 were obtained. The same pulsations were observed on the electromagnetic torque Te (Nm) while on the voltage waveform harmonic distortion of the 3rd and 2nd order were

observed on the lower graph of Figure 4. These distortions affect the voltage profile adversely by distorting the fundamental waveform.

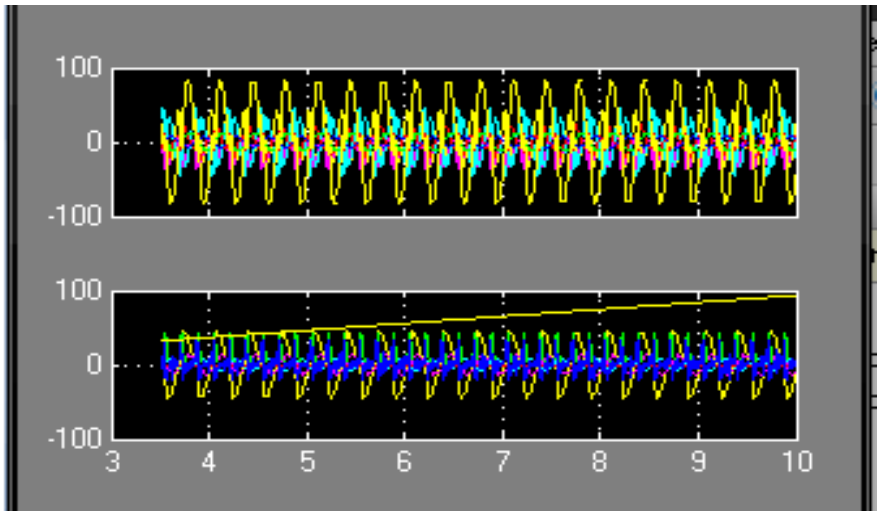


Figure 4: Electromagnetic torque –Nm and voltage

From the preliminary results obtained conclusions were drawn and recommendations made.

4.0 Conclusions and Recommendations

The conclusions and recommendations of this paper are summarized as follows.

( ) The case study results have shown that the domestic electricity peak load power is large enough at 6.683MWp to deserve attention and management.

(i) The results obtained so far reveal that domestic equipment causes some harmonic distortion to the supply voltage. There is need for filtering mechanisms.

(ii) For use with solar PV systems, it is recommended that the solar PV system in cooperate second and third order harmonic filters.

(iii) The national urban domestic load is substantial and needs to be addressed to mitigate the national peak power demand.

(iv) Further studies will be done to investigate other effects and mitigation methods.

Acknowledgements

The authors acknowledge the National Council for Science and Technology (NCST) for funding the study, the National Social Security Fund (NSSF) and Jomo Kenyatta University of Agriculture and Technology for facilitating the study.

References

Hiskens I. A., Milancov: 'Load modeling in studies of power system damping' IEEE transanctions on power systems, Vol. **10**(4), pp 1781 1995.

Renewable energy focus solar PV.

KenGen National energy report (2006).

Arbi Gharakhani; Pragasen Pillay and Sheldon S. Williamson. 'A case study of PV installation for an Urban Building in Downtown Montreal" IEEE 2009, Grid connected solar PV, pp 1- 4

Embakasi Nyayo Estate project report NSSF 1997.

Lijun Gao, R.A. Doungal, Rapidly Fluctuating Shadow Conditions, IEEE Transanctions on Industrial Electronics, Vol 56, May 2009.

DISSEMINATION OF SENBAKOKI (RICE THRESHING TOOL) IN MWEA

H. Murage[1] and E. Gichuhi[1]

[1]Department of Horticulture, Jomo Kenyatta University of Agriculture and Technology Nairobi, Kenya

ABSTRACT

The objective of this survey was to introduce a new rice threshing technology to the rice farmers in Mwea that is efficient and affordable. From the results obtained most farmers felt that the Senbakoki was less tedious and less time consuming. However, the results showed that the adoption rate of the Senbakoki by the farmers was low due to the constraints faced while using the Senbakoki such as sticking of the straw on the combs.

Key words: Rice thresher, Senbakoki, rice threshing efficiency

1.0 Introduction

Rice threshing is the process of separation of grain from stalks and husks. For many years, rice grain has been separated manually. The harvested rice straw is hit against a hard ground surface to separate the seeds from the stems. The hard ground is always covered with a polyethylene sheet where the seeds collect. This leads to a mixture of rice with debris of varied origin, notably soil and small pebbles; even metallic debris. Winnowing does not remove such debris completely. This is the principal cause of wear of the mill huskers which are seldom provided with pre-cleaners. This method of threshing rice is also known as the traditional method. It is tedious, very laborious and time consuming. Observing that poor threshing conditions are counter-productive from the point of view of milling and final quality of the rice, research and development bodies have worked on the design and dissemination of improved threshing technologies. The improved threshing technologies include: the threshing table, motorized threshers, votex thresher and combined harvesters (FAO, 1994). These threshers which cost 2.8-2.9 million francs CFA (~5000 $US) have a rate of separation grain straw of 99%. According to the conditions of Sub-Saharan Africa where 80% of the farmers exploit small-scale farms (Bobobee, 1993; Phillip, 1993; Faure, 1994) and 43% of the total population live below the poverty line, less than 1.00 $US per day (Sims & Kienzle, 2006). The mechanized threshers mentioned are too expensive for the common Kenyan rice farmer.

In rice production, appropriate rice threshing equipment should contribute to the broad objective of increasing the viability of the small farm. Small farmers are currently employing traditional technologies that are inefficient and they often cannot improve this technology because of the leap in scale and capital cost to commercially available equipment. It is therefore the goal of intermediate technology proponents to help fill this gap with good quality rice threshing equipment that are affordable and suited to the scale of operations of the small farmers. However, there is a tendency for equipment development and commercial firms to concentrate their energies on rice threshers that are affordable only to the wealthier farmers. This happens in part because of a focus on what technically could be done, without attention to financial constraints faced by the typical small farmer. Contributing factors include the inappropriate application of industrialized, extensive farming strategies to small intensive farming communities, and the failure to include the small farmer in the process of identifying helpful new technologies that can truly fit into the existing farming system. The result is usually either outright failure of innovations to attract interest or the consolidation of landholdings by wealthier farmers taking advantage of the newly available technology. The position of small scale farmer may become worse, and that of small farmer in general is not improved. Appropriate rice threshing technology advocates must be careful to avoid repeating these mistakes. Therefore, dissemination of a thresher with a high capacity output, available and affordable is necessary.

The Senbakoki was developed in Daikumura currently part of Takaishi City in Osaka Prefecture during the Genroka Period (1688 – 1704). It consists of a waist-high wooden frame from which teeth protrude. These teeth are made of iron or bamboo and make this agrarian tool look like a giant comb. Rice stalks are pulled through this comb to separate the grains from the stems. Until the introduction of the Senbakoki, a primitive implement called kokibashi was used to thresh rice. This was basically a split piece of bamboo, often compared to giant chopsticks, through which the stalks were pulled to remove the grains. It was slow and labourous. The Senbakoki therefore greatly improved the efficiency of threshing. However, the Senbakoki faded away after the introduction of western farming technologies during the 20th century. The introduction of the Senbakoki to the small scale farmers in Kenya will greatly improve the efficiency of threshing rice. The equipment is cheap as compared to the currently high priced combined harvesters and mechanized threshers. It is composed of cheap available materials which have been put together in a simple design to construct the equipment. It is therefore equipment that the Jua kali artisans can easily fabricate using the locally available materials and sell it cheaply to the small scale farmers.

Rice threshers (Senbakoki) were disseminated to the rice farmers in Mwea, by the Research and Extension department in Jomo Kenyatta University of Agriculture and Technology. The adoption rate of the Senbakoki by the rice farmers in Mwea was then assessed. The objective of dissemination of the Senbakoki was to provide the rice farmers in Mwea region with an alternative, better and efficient method of threshing rice.

2.0 Methodology

Sixteen Senbakoki were disseminated in Mwea rice growing region. This was done in collaboration with the Mwea Irrigation Agricultural Development (MIAD). A questionnaire was then administered to the farmers who had used the Senbakoki. The answered questionnaires were then analyzed.

3.0 Results

85% of the respondents had used the Senbakoki rice threshing tool to thresh rice, while 15% of the respondents had not used the Senbakoki. The 15% may not have had a chance to access the Senbakoki even after hearing about it (Figure 1). 5% of the respondents felt that the use of Senbakoki was an efficient method of threshing rice while 95% felt that it was not efficient enough (Figure 2). 15% of the respondents would prefer to hire the Senbakoki, while, 85% would not (Figure 3). 15% of the respondents would prefer to buy their own Senbakoki, while 85% would not (Figure 4). The respondents cited the following as the major problems facing the use the Senbakoki; 35% said it was time consuming, 5% said they were experiencing mechanical problems, 20% said that it was tedious, 32% said that the straw stuck on the combs during threshing (Figure 5). All the farmers interviewed preferred the traditional method of threshing rice as opposed to the use of the Senbakoki threshing tool. This indicates that majority of the farmers are not ready to adopt the new technology of threshing rice.

4.0 Discussion and Conclusion

An output capacity of approximately 2 tons per day can be achieved by use of Senbakoki rice threshing tool. From the results, less complaint concerning broken grains was registered after using the Senbakoki to thresh rice. Irrational harvest and the rudimentary postharvest operations are factors of losses of rice that can reach 35%. The inefficiency of manual threshing and winnowing, seasonal drudgeries of the women and the children in Kenya worsens its losses. Damaged and broken grains sensitive to the damage of storage and commercial low value are obtained. Manual threshing and winnowing being already arduous require more labour (Azouma *et al.*, 2009). The farmers felt that the Senbakoki was less tiring to use. In the Mwea rice farming zone, threshing is often carried out manually giving an output capacity $\leq$ 1 ton per day (Gret *et al.*, 1993; Akintayo et al., 2008). The motorized and mechanized threshing-machines are practically non-existent on the sites of rice production. However, there seemed to be lack of willingness to adopt the new technology of threshing rice using the Senbakoki, by the farmers in Mwea. Although from a previous research, the method had shown to be more efficient in terms of output per acre. According to the technology adoption lifecycle model, the adoption or acceptance of a new product or innovation is in line with the demographic and psychological characteristics of defined adopter groups. The process of adoption over time is typically illustrated as a classical normal distribution or "bell curve." The model indicates that the first group of people to use a new product is called "innovators," followed by "early adopters." Next come the early and late majority, and the last group to eventually adopt a product are called "laggards." The reluctant to adopt the Senbakoki by the Mwea farmers was in line with this model. Only 5% of the farmers felt that Senbakoki was more efficient than the traditional

method of threshing rice (Figure 2). These 5% of the farmers represent the innovators group. 15% of the farmers also preferred to own a Senbakoki (Figure 4). This shows that they were ready to use the Senbakoki.

The reasons behind lack of willingness to adopt the Senbakoki were as follows (Figure 5): 35% of the farmers found the method to be time consuming because one has to keep on removing stuck rice straw on the comb. 20% of the farmers found the method to be tedious. 32% of the farmers found the method cumbersome because one needs to keep on removing the straw stuck on the combs. In addition a few farmers complained about the grains hitting them on the face during threshing using the Senbakoki. Some also felt that the Senbakoki rice threshing tool is quite small in size to thresh a large amount of rice harvested. If the following concerns were addressed, more farmers in Mwea region would be ready to adopt the Senbakoki threshing tool.

The adoption of the Senbakoki by rice farmers would reduce grain losses, increase the production and improve the working conditions. In addition, there would be a drastic reduction in drudgery and improve upon the quality of threshed crops. Widely adoption of the Senbakoki would not only improve the livelihood of the farmers but also the country's economy.

5.0 Recommendations

In order for the farmers to fully accept the new technology, the following improvements should be done: The length of the combs should be reduced to minimize the tendency of the straw sticking on the combs. The spacing between the combs should also be widened; the support base is weak and thus should be reinforced number of combs per machine should be increased so as to increase the number of people working at a time; have a properly designed large sized Senbakoki rice threshing tool.

6.0 Acknowledgement

We would like to thank Research Production and Extension (RPE) division of Jomo Kenyatta University of Agriculture and Technology for provision of the funds to carry out the study. We are grateful to Mwea Irrigation Agriculture Development (MIAD) for their collaboration in dissemination of the Senbakokoki (rice thresher) to the farmers in Mwea.

References

Akintayo, I., Cissé, B. and Zadj, D. L . (2008). Guide pratique de la culture des NERICA de plateau. Centre du riz pour l'Afrique (ADRAO/WARDA), Cotonou.

Anonymous,(1996). Caractéristiques structurelles de l'agriculture togolaise, Rapport principal, Ministère de l'Agriculture, de l'Elevage et de la pêche du Togo.

Anonymous. (1998). Ministère de l'Agriculture et des Ressources Animales, Burkina Faso Enquête Nationale de Statistiques Agricoles 1993, Rapport général.

Azouma, O. Y., Porosi, M. and Koji Yamaguchi, K. (2009). Design of throw-in type rice thresher for small scale farmers. *Indian Society for Education and Environment* Vol.**2**(9) ISSN: 0974- 6846

Bobobee, E. Y. H. (1993). Energie humaine et animale dans les systèmes agricoles du Ghana: quelques expériences pp. 132136. In: FAO, Energie humaine et animale dans la production agricole. Actes de l'atelier, Harare, Zimbabwe 18-22 janvier 1993.

Bohlen, Joe M., Beal, George, M. (1957). "The Diffusion Process", *Special Report No. 18* (Agriculture Extension Service, Iowa State College) **1**, 56–77.

FA0. (1994). African experience in the improvement of post-harvest techniques the Informartion Network on Post-Harvest Operations (INPhO) Rome, Italy.

Faure, G. (1994). Mécanisation, productivité du travail et risque: le cas du Burkina Faso. Econ. rurale N°219.

Groupe de Recherche et d'Echanges Technologiques (GRET) et al. (1993). Matériels pour l'agriculture. 1500 références pour l'équipement des petites et moyennes exploitations. ITDG, GRET et CTA, Saint-Etienne, Impressions DUMAS.

International Rice Research Institute (IRRI) .1981. Drawing and Test Standard Paper of Throw-in Type thresher.

Phillip, D. O. A. (1993). Aspects économiques de la traction animale au Nigeria: aperçu de la situation. **In**: FAO, Energie humaine et animale dans la production agricole, Actes de l'Atelier, pp: 128-131. Harare, Zimbabwe 18-22.

Sims, G. B. and Kienzle, J .(2006). Farm power and mechanization for small farms in sub-saharan Africa. FAO, pp: 5-10. Research article "Low cost paddy thresher" Azouma et al.

Website: http://oldphotosjapan.com/images/185t.jpg . Posted by Kjeld Duits • 2008-05-15,

Appendix
Figures

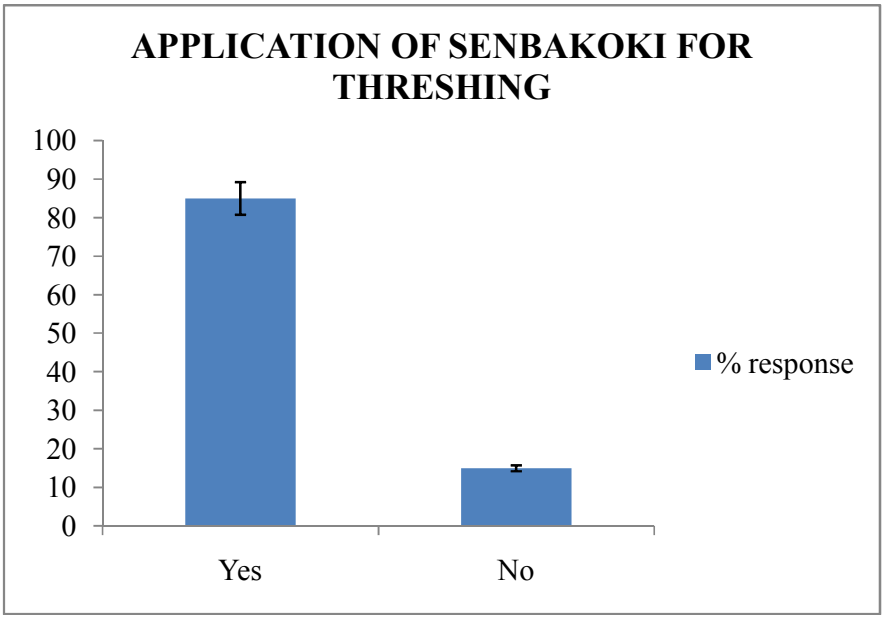


Figure 1: A graph showing the relative use (%) Senbakoki rice threshing tool by farmers in Mwea

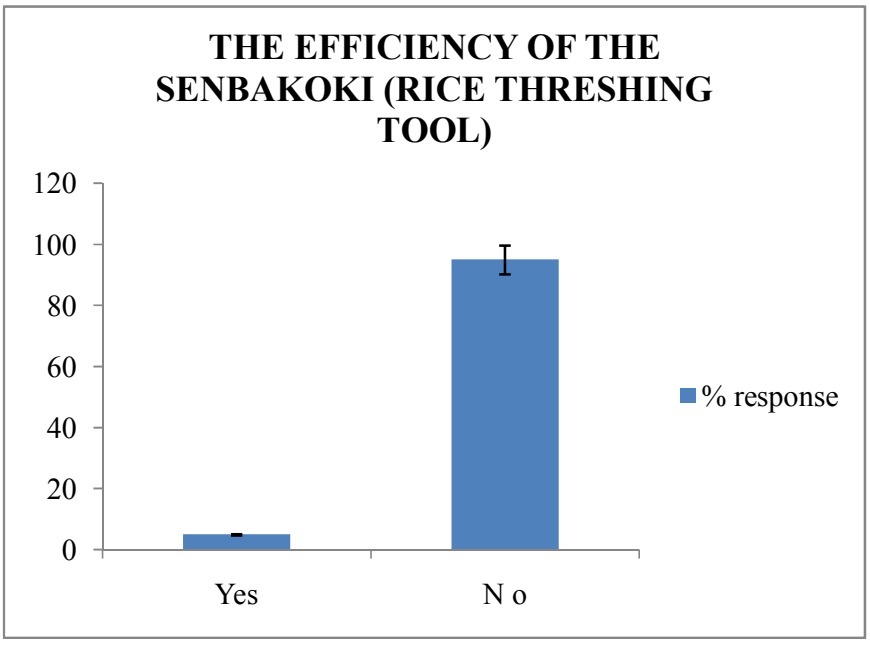


Figure 2: A graph showing the relative efficiency (%) of the Senbakoki rice threshing tool by farmers in Mwea

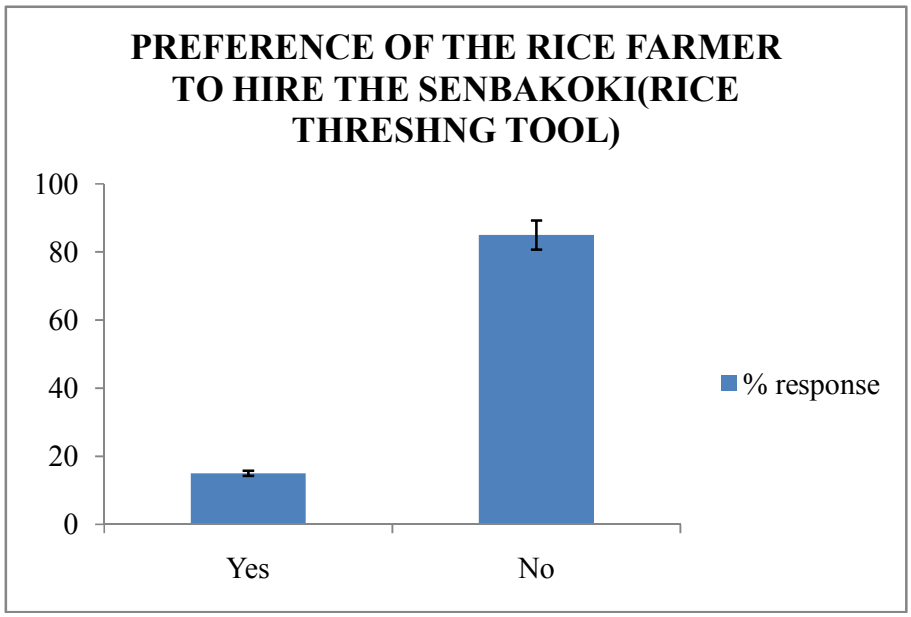


Figure 3: A graph showing relative preference (%) of the farmers in Mwea to hire a Senbakoki rice threshing tool

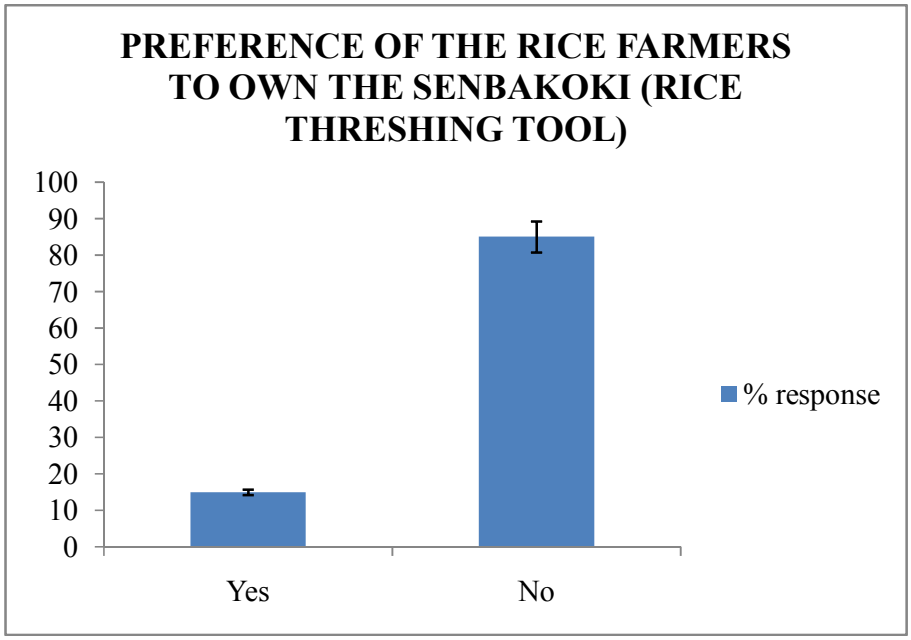


Figure 4: A graph showing relative preference (%) of the farmers in Mwea to own a Senbakoki rice threshing tool

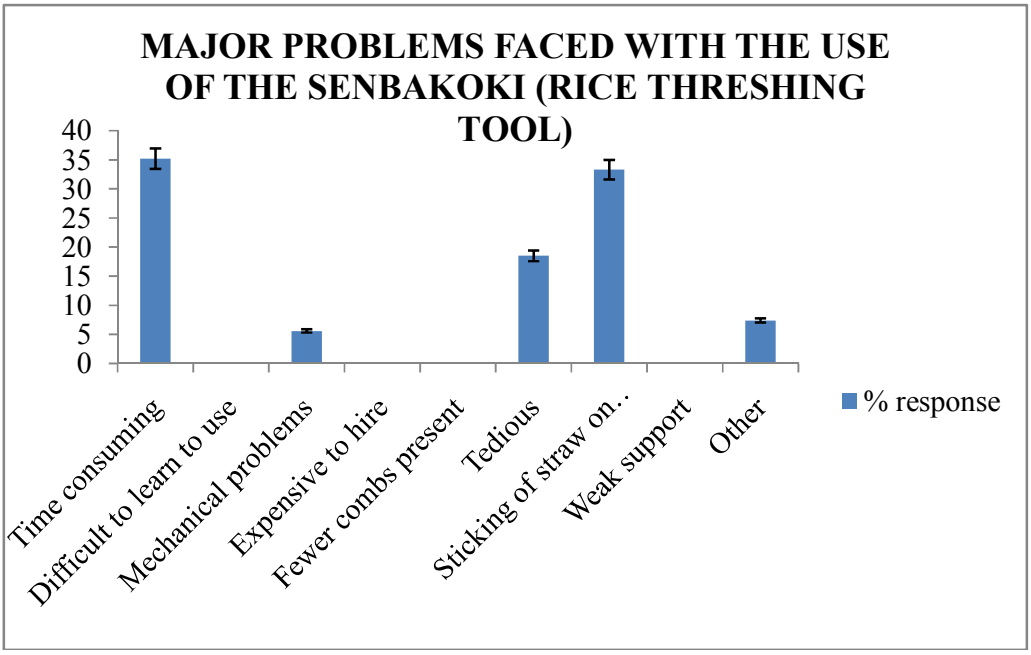


Figure 5: A graph showing the relative percentage of the problems farmers in Mwea face while using the Senbakoki rice threshing tool

OPTIMIZING LQR TO CONTROL BUCK CONVERTER BY MESH ADAPTIVE SEARCH ALGORITHM

M. M. Kanai[1], J. N. Nderu[2] and P. K. Hinga[3]
Department of Electrical and Electronics Engineering, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: cheptora@yahoo.com

Abstract
In this study, control method to control Buck converters by Linear Quadratic Regulator (LQR) controllers is employed. Systems with conventional LQR controllers present good stability properties and are optimal with respect to a certain performance index. However, LQR control does not assure robust stability when the system is highly uncertain. In this paper, a convex model of converter dynamics is obtained taking into account uncertainty of parameters. In order to apply the LQR control in the uncertain converter case, the performance index is optimized by using Mesh Adaptive Search (MADS). As a consequence, a new robust control method for dc–dc converters is derived. This LQR-MADS control is compared with normal LQR design. All the analysis and simulations on the above converter is by MATLAB software. The simulation results show the improvement in voltage output response.

Key words: Linear quadratic regulator (LQR), mesh adaptive search (MADS), DC-DC converter, voltage control

1.0 Introduction

The DC converter is a device which transforms AC power to DC. This device is also known as an AC to DC converter. A Chopper can be considered as a DC equivalent of an AC transformer with a continuously convertible constant. Like a transformer, the converter can be employed for stepwise increase or reduction of DC source voltage. The converters are wildly used for the control of motor voltage in electric cars, ceiling elevators, mine excavation etc. Their specific features are the precise control of acceleration with high efficiency and fast dynamic response. Converters are also employed in DC motors to return the energy to its source. In this way, it results in the saving of energy in the transportation systems in prolonged stoppage. Converters are also used in DC voltage regulators along with an inductor to produce a DC current source especially for the current source inverters.

Some control methods have stated the issue of control through pole placement as with Kelly and Rinne, (2005). Another method is the use of state feedback in the control of DC-DC converters as stated by Keller, et al 2005). In modeling area of DC-DC converters, a variety of models are presented which comprise desirable responses by administration of control methods. Most of the articles have concentrated on design of PI and PID controllers as in Uran and Milanovic, (2003) and Namnabat, *et al.*, (2007)]. The feedback loop is another control method used by He and Luo, (2004). The use of LQR method for the improvement of Buck converter function is the subject presented by Leung, *et al*., (1993), Bayati *et al*., (2007) and Mohammad. (2007)]. Linear state feedback controls are among the simplest way of feedback control scheme especially for system with multi outputs. When the model is obtained in state space, then the state feedback control can be designed based on it. Commonly, the state feedback control gains can be determined by means of linear quadratic regulator (LQR) method via solution of Riccati equation or pole placement method as indicated by Ogata, (2002). However, these approaches still possess trial and error approach of parameter adjustment. Particularly, choosing elements of Q and R matrices in the feedback control design using LQR method has to be done by trial.

In this paper an optimum LQR is designed that can improve the Buck converter response. There is no specific method in LQR design which is based on trial and error. The best constant values for state feedback matrix are laboriously obtained through trial and error, although time consuming. Genetic algorithm is employed to find the best values for LQR controller in a very short time. Therefore, a new method is presented for optimizing the systems with two factors of the least response time and the highest precision.

2.0 Materials and Methods

2.1 Buck Converter Circuit Model

The Buck converter circuit model is depicted in Figure1.

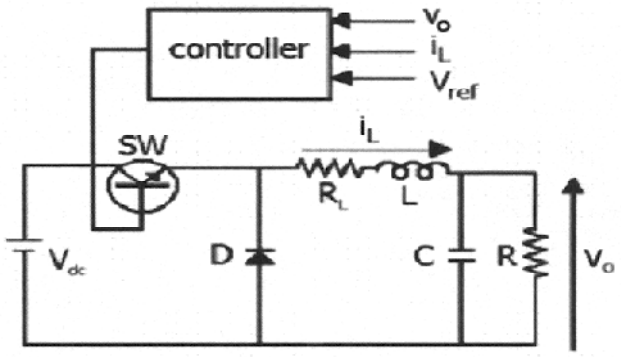


Figure.1: Buck converter

In this model, Vo is the system output voltage and Vref *,* is the converter voltage. To obtain the converter state equations in low-frequency state, it is required that the system state be studied in two states of on and off as shown in Fig. 2, and Fig.3

2.1 Switch ON:

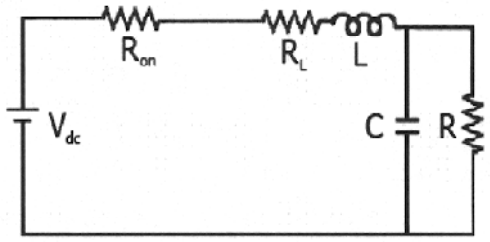


Figure.2: Circuit topology during T_{on}.

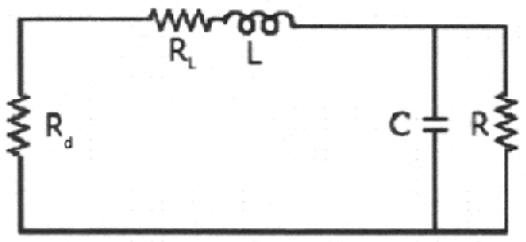


Figure.3: Circuit topology during T_{off}

$Vdc - V_0 = (Rs + RL)iL + L(diL / dt)$,

$i_L = C(dV_0 / dt) + V_0 / R$,

…… (1)

$X_1 = i_L$, $X_2 = V_o$, $X = \begin{bmatrix} X_1 \\ X_2 \end{bmatrix}$

$X = A_lX + B_lV_{dc}$ '

2.2 Switch OFF:

$(R_d + R_L)i_L + L(di_L/dt) + V_o = 0$,

$i_L = C(dVo/dt) + Vo/R$,

$X = A_2X + B_2V_{dc}$ …… (2)

$$A_2 = \begin{bmatrix} \frac{-(R_L + R_d)}{L} & -\frac{1}{L} \\ \frac{1}{C} & -\frac{1}{RC} \end{bmatrix}, \quad B2 = \begin{bmatrix} 0 \\ 0 \end{bmatrix}.$$

Now it is required to show the effect of on and off durations of switch in (1) and (2) to obtain the mean values of state equations.

$X = AX + BV_{dc}$

$A = mA_l + (l - m)A_2$
$B = mB_l + (l - m)B_2$……. (3)

$$m = \frac{t_{on}}{T_s} \quad .$$

2.2 Linear Quadratic Regulator (LQR) Designing Methodology

The LQR design problem has been extensively investigated for the past four decades. It is possible to improve the converter response by employing the LQR control method. Application of the LQR involves choosing the positive definite state and control input matrices, *Q* and *R* that provide satisfactory closed-loop performance. The closed-loop eigenvalues are related to these weighting matrices. Many methods are available for determining weighting matrices, with the closed loop poles placed in a specified region of the complex plane. A sequential procedure which selects the weighting matrix *Q* and degree of relative stability to position individually and arbitrarily the real parts of the eigenvalues of the optimal LQR system has been presented by Qi. Feng, et al (*2002*). Many methods are available for determining weighting matrices, with the closed-loop poles placed in a specified region of the complex plane. R. L. Haupt and S. E. Haupt,(2004) used sequential method with classical root-locus techniques has been developed for determining the weighting matrices in the frequency domain to retain closed-loop eigenvalues in a desired region in the complex plane. But the main method is based on trial and error, although time consuming. In this method, the feedback gain matrix is determined if *J* energy function is optimized. To achieve equilibrium among range control parameters, response speed, settling time, and proper overshoot rate, all of which guarantee the system stability, the LQR is employed.

2.2.1 LQR Algorithm

For a system in the form of
$X=AX+BU$ ……(4)

The LQR Method determines the K matrix of the equation
$U(t)=-KX(t)$……(5)
to minimize
$J = \int (X^TQX + U^TRU)\, dt$ ……(6)

Function .R and Q matrices express the relation between error and energy expense rate. R and Q are also the definite positive matrices. From the above equation, we have:
$J= \int(X^TQX+X^TK^TRKX)dt$ …… (7)
$=\int(X^T(Q+K^TRK)X)dt$
Subsequent to the solution stages of the equation and optimization of the parameters of the following equation:
$X^T(Q + K^TRK)X = d/dt(X^TPX)$

The following equation is presented:
$X^T(Q+ K^TRK)X=-X^TPX -X^TPX$
$=X^T[(A \_BK)^T P +P(A -BK)]X$ …… (8)
With regard to the values on the both sides of the above equation and with regard to this fact that these equations are true for every X, then the following equation is obtained:
$(A - BK)^TP+ P (A - BK) = -(Q+ K^TRK)$……(9)
If $R= T^T.T$ matrix is positive and definite and T matrix is also gross:
$A^TP+PA+ [(TK-T^T)^{-1}B^TP]^T*[TK-(T^T)^{-1}B^TP]-PBR^{-1}B^TP+Q=0$…… (10)

For quantifying J in relation to K we have:
$X^T[TK - T^{-T} B^TP]T\, TK - T^{-T} B^TP]X$ ……(11)

This equation is non-negative and the minimum amount takes place when it is zero or when:
$TK=T^{-1}TB^{T}P$
So;
$K = T^{-1}T^{-T} B^{T}P= R^{-1}B^{T} P$ ……(12)
We can also obtain the control matrix for U input.
$U(t) = -KX(t) = -R^{-1}B^{T}PX(t)$……(13)
And P should be true in the following Riccati equation.
$A^{T}P+PA-PBR^{-1}B^{T}p+Q=O$ …….. (14)
In LQR design, Rand *Q* weight matrix which determines the quotient related to the closed loop feedback system within the least time is determined. The selection of R and *Q* has the least dependence on the specification of system administration and requires a long range of trial and error.

2.3 Mesh Adaptive Search Algorithm (MADS)

Mesh Adaptive Search Algorithm **(**MADS**)** optimization routine is an evolutionary technique that is suitable to solve a variety of optimization problems that lie outside the scope of the standard optimization methods. Generally, MADS has the advantage of being very simple in concept, and easy to implement and computationally efficient algorithm. Unlike other heuristic algorithms, such as GA, MADS possesses a flexible and well-balanced operator to enhance and adapt the global and fine tune local search. A historic discussion of direct search methods for unconstrained optimization is presented by R. M. Lewis, V. Torczon, and M. W. Trosset(2000). The authors gave a modern prospective on the classical family of derivative-free algorithms, focusing on the development of direct search methods. The algorithm proceeds by computing a sequence of points that may or may not approaches to the optimal point. The algorithm starts by establishing a set of points called *mesh*, around the given point. This current point could be the initial starting point supplied by the user or it could be computed from the previous step of the algorithm. The mesh is formed by adding the current point to a scalar multiple of a set of vectors called a *pattern*. If a point in the mesh is found to improve the objective function at the current point, the new point becomes the current point at the next iteration. This maybe better explained by the following:

First: The Pattern search begins at the initial point 0 *X* that is given as a starting point by the user. At the first iteration, with a scalar =1 called *mesh size,* the pattern vectors are constructed as [0 1], [1 0], [−1 0] and [0 −1], they may be called direc on vectors. Then the Pa ern search algorithm adds the direction vectors to the initial point X_0 to compute the following mesh points:X_0 + [1 0],X_0 + [0 1],X_0 +[−1 0] and X_0 + [0 −1].

Figure.4 illustrates the formation of the mesh and pattern vectors. The algorithm computes the objective function at the mesh points in the order shown.

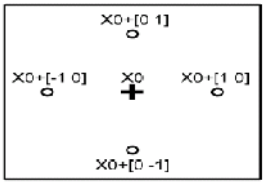


Figure 4: Mesh points and the Pattern illustration

The algorithm polls the mesh points by computing their objective function values until it finds one whose value is smaller than the objective function value of X_0. If there is such point, then the poll is successful and the algorithm sets this point equal to *X*1.After a successful poll, the algorithm steps to iteration 2 and multiplies the current mesh size by 2, (this is called the *expansion factor* and has a default value of 2). The mesh at iteration 2 contains the following points: 2*[1 0] + X_1, 2*[0 1] + X_1, 2*[-1 0] + *X*1 and 2*[0 -1] + *X*1. The algorithm polls the mesh points until it finds one whose value is smaller the objective function value of X_1. The first such point it finds is called X_2, and the poll is

successful. Because the poll is successful, the algorithm multiplies the current mesh size by 2 to get a mesh size of 4 at the third iteration because the expansion factor =2.

Second: Now if iteration 3, (mesh size= 4), ends up being unsuccessful poll, i.e. none of the mesh points has a smaller objective function value than the value at X_2 , so the poll is called an unsuccessful poll. In this case, the algorithm does not change the current point at the next iteration. That is, $X_3 = X_2$. At the next iteration, the algorithm multiplies the current mesh size by 0.5, a contraction factor, so that the mesh size at the next iteration is smaller. The algorithm then polls with a smaller mesh size, this is shown by The Math works (2010),A.K.Al-Othman, et al,(2008) and R. M. Lewis, and V. Torczon (2007)].The optimization algorithm will repeat the illustrated steps until it finds the optimal solution for the minimization of the objective function.

2.3.1 Tuning R and Q using MADS

It is not a trivial problem to find the optimal *K* since the control performance depends on choosing weighting matrices. In this paper, weighting matrices are decided by the genetic search to obtain the best *K* for the optimal LQR design.

The target function is as follows:

$$Fobj = \{tr^{0.2} + ts^{0.5} + Ess^{5} + Mp^{2}\}. \qquad (15)$$

That tr is rise time, ts is settling time, Mp is overshoot and Ess is steady state error.

3.0 Results and Discussions

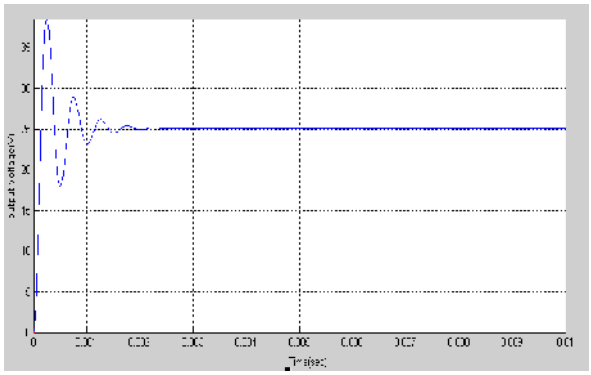


Figure .5: Open loop output voltage response

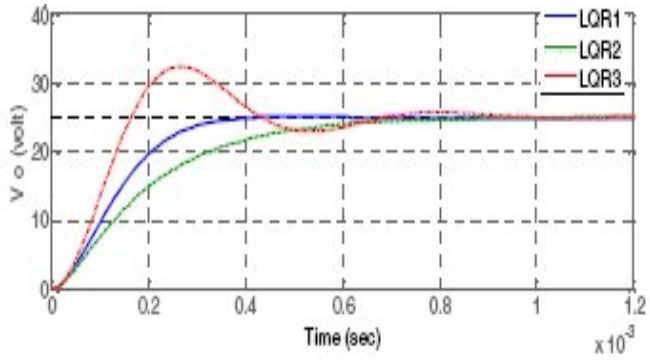


Figure.6:simple LQR output voltage responses

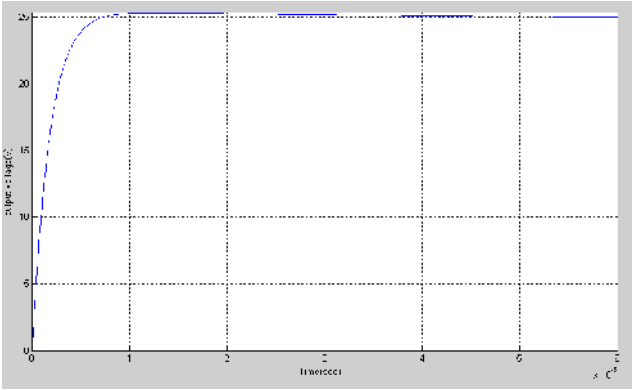


Figure.6: LQR-MADS output voltage response

TABLE1: LQR Parameters

	Q11	Q22	R11
LQR1	1.01	0.001	7.95
LQR2	663.9	0.016	1999.4
LQR3	19.1	0.007	1105.6
LQR-MADS	257.5	0.002	1823

Table2: Simulation results

	rise time(s)	over-shoot (%)	steady state error(%)	settling time(s)
OPEN-LOOP	94.9ms	53.5	0.1	1.56ms
LQR1	0.25ms	1.50	0	0.324ms
LQR2	0.423ms	0	0.05	0.741ms
LQR3	0.15ms	29.1	0.2	0.849ms
LQR-MADS	1.9µs	1.2	0	0.05ms

4.0 Conclusion

The reduction of output voltage ripple of the converter is very important. The optimum design method for linear controller is able to control the dynamic behavior of the converter. The using of mesh adaptive algorithm for the calculation of optimum coefficients of the matrices in the design of LQR controllers can bring about optimum dynamic response. In this paper, a LQR controller is designed to improve the Buck converter performance, in this way, mesh adaptive algorithm is used

to optimize the LQR matrices. The results of simulation prove the improvement of the functioning of this converter compared with simple LQR method as there is a significant reduction in rise time and settling time which indicate that the system is quite fast.

References

Al-Othman, A. K. and EL-Nagge, K. M. (2008). Application of Pattern Search Method to Power System Security Constrained Economic Dispatch,World.

Leung, F. H. F., Tam, P. K. S. and Li, C. K. (1993). An improved LQR-based controller for switching DC-DC converters, *IEEE Trans., Ind Electron*, pp 521 – 528.

Keller, I. G., Lasea, D. and Myrzik, J. M. A. (2005). State-space Control structures For Buck Converters with without Input Filter, IEEE**.,** Power Electron,European Conference. September, pp 10.

Kelly, and Rinne, K. (2005). Control of DC-DC Converters by direct pole placement and adaptive feed Forward gain adjustment, IEEE.

Bayati, M. Eshtehardiha, P. S. and Namnabat, M. (*2007*). Optimized State Controller on DC-DC Converter.The7th International Conference on Power Electronics 22-26, Exeo, Daegu Korea.

Mohammad, P., Saeid, E., *A*rash, K. and Mohammad, A. (2007). Optimizing LQR and Pole placement to Control Buck Converter by Genetic Algorithm, International Conference on Control, Automation and Systems PP. 17-20, in COEX, Seoul, Korea.

Namnabat, M., Bayati Poodeh, M., and Eshtehardiha, S. (2007). Comparison the Control Methods In Improvement thePerformance of the DC-DC Converter, International Conference on Pow Electronics (ICPE07), pp. 246-251.

Ogata, K. (2002). Modern Control Engineering. New Jersey: Prentice Hall.

Qi. Feng, Hung, J. Y. and Nelms, R. M. (2002). The application of posicast control to DC-DC converters,.37th Intersociety Energy Conversion Engineering Conference (IECEC.).

Haupt, R. L. and Haupt, S. E. (2004). Practical Genetic Algorithms, New York: Wiley.

Lewis, R. M. and Torczon, V. (2007). A globally convergent augmented lagrangian pattern search algorithm for optimization with general constraints and simple bounds, *SIAM Journal on Optimization*, vol. **12**, pp 1075-89.Academy of Science, Engineering and Technology 25.

Lewis, R. M., Torczon, V. and Trosset, M. W. (2000). Direct search methods: then and now. *Journal of Computational and Applied Mathematics*, vol. **124**, pp. 191-207.

Uran, S. and Milanovic, M. (2003). State controller for Buck converter, *Eurocon, 2003. IEEE* vol. **1**, pp.381 – 385.

The Math works (2010). Global Optimization Toolbox, User's Guide, documentation.

He, Y. and Luo, F. L. (2004). Study of sliding mode control for DC-DC converters. *Power Conversion* ,vol. **2**, pp. 1969 –1974.

PASSIFLORA EDULIS SEED OIL METHYL ESTER AS A POTENTIAL SOURCE OF BIODIESEL

G. T. Thiongo[1], P. N. Kioni[2], S. N. Mirie[3], P. N. Kariuki[4], and W. S. Namaru[5]
[1,3]Department of Chemistry, Jomo Kenyatta University of Agriculture and Technology,Thika, Kenya
[2,4]Kimathi University College of Technology, Nyeri, Kenya
[5]Kenya Bureau of Standards
E-mail:georgethuku@ymail.com

Abstract
The fact that fossil energy reserves are limited coupled with the environmental pressure resulting from their use has encouraged research on biodiesel and other biofuels. Biodiesel is a nontoxic, biodegradable and renewable source of energy made by the transesterification of oils or fats with short chain alcohols. This study was focused on the use of *Passiflora edulis* seed oil (Passion fruit).This oil was obtained from an industrial fruit juice processing waste. The oil was evaluated as a good potential feedstock for production of biodiesel. In this study *Passiflora edulis* seed oil was successfully transesterified using methanol and KOH as a catalyst.A biodiesel yield of 80% was obtained. The biodiesel had a viscosity of 4.60 mm^2/s, acid value 0.45 mgKOH/g, density of 0.89g/ml, colour 1.60, water content 0.2%, copper strip corrosion-No tarnish, and flash point > 150 ^0C .The fuel parameters measured were within range according to the American Society for Testing and Materials (ASTM) and International Standards Organization (ISO) test methods apart from the percentage water content.

Key words: *Passiflora edulis* seed oil, biodiesel, transesterification, catalyst

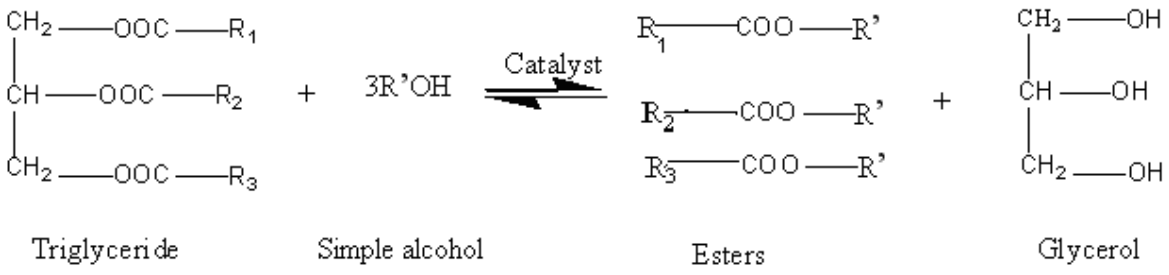
1.0 Introduction

The predicated shortage of fossil fuel coupled with the increase in fuel prices has encouraged the research for other substitutes such as biodiesel. Biodiesel can be defined as the alkyl ester of fatty acids, made by the transesterification of oils or fats, from plants or animals, with short chain alcohols such as methanol and ethanol (Pinto *et al*., 2005). Besides being renewable, biodiesel can also be used directly in most diesel engines without requiring extensive engine modifications (in contrast to other "eco-fuels" such as hydrogen). Other advantages include reduced CO, hydrocarbons, and particles in exhaust emission.Table1 (Kiss *et al*., 2005) shows the average emissions compared to conventional diesel where B20 means a blend of 80% petroleum diesel and 20% biodiesel and B100 means biodiesel in its pure form.

Table 1: average biodiesel emmisions compared to conventional diesel

Emission type	B20	B100
Total unburned hydrocarbons	−20%	−67%
CO	−12%	−48%
CO_2	−16%	−79%
Particulate matter	−12%	−47%
NO_x	+2%	+10%
SO_x	−20%	−100%
Polycyclic aromatic hydrocarbons (PAHs)	−13%	−80%
Nitrated PAHs	−50%	−90%

There have been many problems associated with using vegetable oils directly in diesel engines. These problems include decrease in power output and thermal efficiency of the engine; oil ring sticking; thickening or gelling of the lubricating oil as a result of contamination by vegetable oils. Another disadvantage of the use of vegetable oils directly is the high viscosity (about 11–17 times higher than diesel fuel) and lower volatility that result in carbon deposits in engines due to incomplete combustion (Pinto *et al*., 2005).Transesterification is widely used to reduce vegetable oil viscosity with most industrial processes employing alkaline catalysis and methanol. The transesterification process reduces the molecular weight in relation to the triglycerides, and also, reduces the viscosity improving the volatility. A basic transesterification reaction can be shown as:



After the reaction, the products are a mixture of esters of fatty acids, glycerol, alcohol, catalyst and a low percentage of tri-, di and monoglycerides. There are over 500 species worldwide of Passiflora in the family passifloraceae. Of these the fruits of only about 20 varieties are edible and only about four varieties are cultivated on a large scale, one of them being ,*Passiflora edulis* Sims which has the most significant commercial value (Nyanzi, *et al*., 2005). Two subvarieties of *P.edulis* Sims namely the purple passion fruit (*P.edulis* Sims Var. *edulis*) and the yellow passion fruit (*P.edulis* Sims Var.*flavicarpa*) grow in Kenya. The aim of this research was to produce biodiesel from *Passiflora edulis* seed oil obtained from industrial fruit juice processing waste.

2.0 Materials and Methods

The reagents used were of analytical grade .Methanol, 2-propanol were purchased from Sigma (Seelze, Germany). Potassium hydroxide was obtained from Rankem (New Delhi India). Toluene was

obtained from Merck (Barcelona, Spain). The vegetable oil was pressed from dry *Passiflora edulis* seeds which was an industrial waste from a fruit processing plant in Kenya. The acid value of the crude oil was first established before any reaction was performed on it.

2.1 Determination of Acid Value

The acid value for the vegetable oil was determined by the method described by Gerpen *et al*., 2004. Two 250ml beakers were prepared by adding 62.5ml of solvent .The solvent consisted of 50% isopropyl alcohol and 50% toluene.2.5g of the crude vegetable oil was added to one of the beakers (sample beaker) and the other beaker left with out a sample (blank beaker). Both beakers were titrated with 0.1N KOH to the first permanent pink color using 2 ml of phenolphthalein as an indicator in each. The procedure was done in triplicate and the average obtained. The acid value (AV) was calculated using the equation,

Acid Value = (A-B) ×N×56.1/W where,

A = Number of ml of KOH needed to neutralize sample beaker, B = Number of ml of KOH needed to neutralize blank beaker, N = Normality of KOH solution, W = Weight of sample used and % F.F.A =1/2 Acid value.

2.2 Transesterification Reaction

The transesterification reaction of *Passiflora edulis* seed oil with KOH was done at room temperature with the help of a hot plate magnetic stirrer (Autoscience AM-5250B, Tianjin Instrument Co.). The amount of KOH and methanol to use for the experiment was calculated according to Gerpen *et al*., 2004. 88.20g (100ml) of *Passiflora edulis* seed oil with a % FFA of 2.41 required 1.25g of KOH while methanol required for the same was 24.65 ml. The KOH crystals were first dissolved in the appropriate amount of methanol and then added to the vegetable oil in a separate conical flask having a magnetic rod placed inside. The flask was then placed in the hot plate and the mixture stirred at a stirring rate of 700rpm for 2 hours. The mixture was then left overnight to settle in a separating funnel .After settling, the mixture separated into two phases, the lower part being glycerin and the upper part the ester layer. The glycerin was then allowed to come out by opening the tap on the separating funnel in order to remain with the ester layer. The ester layer was then transferred to a vacuum rotary evaporator set at 65^0C to remove any excess methanol left. The ester layer was washed by placing it in a separating funnel and spraying warm water (40^oC) representing a quarter amount of the biodiesel being washed using a spraying can and removing the water at the bottom of the funnel. This was done until the wash water did not turn pink on addition of phenolphthalein indicator, indicating that the catalyst was washed out. The ester layer was dried after washing by heating the layer at 60^0C in a beaker until the layer changed from being cloudy to clear indicating that the water had been evaporated. The % yield from the reactions was obtained by dividing the weight of biodiesel obtained with the initial weight of the vegetable oil started with and it was obtained by performing triplicate reactions and obtaining the average. Other parameters measured after obtaining the biodiesel are viscosity, water content, flash point, copper strip corrosion, colour, density and acid value and the results are show in table 1.

3.0 Results

Table 1: Fuel properties measurement

Property	Method	Apparatus	limits	CSEK
Density @ 20^{o}C (kg/m^{3})	ISO 12937	S.G density meter (DMA 4500)	860-900	887
Kinematic viscosity at 40^{0}c (mm^{2}/s)	ISO 3104	Automatic viscometer (HMV 472 HERZOG)	3.5-5.0	4.6
Astm colour	ASTMD 1500	Tintometer (Lovibond PFX880)	Max 3.5	1.6
Copper strip corrosion (3h at 50^{0}c rating, Max)	ISO 2160	Air oven, (Memmert)	Class 1	No tarnish
Density @15 ^{o}C (kg/ m^{3})	ISO 12185	Density meter (DMA4500)	860-900	891
Flash point ^{o}C, min	ASTMD 93	Pensky Martens closed cup tester	130 min	>150
Water content % v/v	ASTM D95	Dean and Stark apparatus	0.05	0.09

3.1 Discussion

From the transesterification reaction the yield of biodiesel from *Passiflora edulis* seed oil was 80.37% by weight of the oil. The theoretical value of 100% was not obtained and this can be attributed to saponification where the free fatty acids available in the oil form salts due to reaction with the catalyst. This could have occurred since the oil had a high acid value of 4.82. The results show that the process of transesterification greatly reduces the viscosity which leads to improved fuel properties of the *Passiflora edulis* seed oil. The flash point for the biodiesel which is an indicator of any residual alcohol left in the biodiesel obtained is above 150^{0}C hence it safe to use as there is no risk of explosion .The copper strip corrosion test shows no tarnish on copper hence the fuel is not corrosive to copper and will not corrode engine parts. All the other properties measured which include density (at 20^{o}C and 15 ^{o}C) and ASTM colour meet the given standard apart from the % water content which was 0.09 compared to the maximum water content required which is a maximum of 0.05%.

4.0 Conclusion and Future Perspective

The results show that *Passiflora edulis* seed oil was successfully transesterified using methanol and KOH as a catalyst judging form the viscosity of the biodiesel obtained. Apart from the water content which can be improved by better drying of the biodiesel, all the fuel properties measured were within range according to International Standards Organization (ISO) and the American Society for Testing and Materials (ASTM) standards. The biodiesel obtained from *Passiflora edulis* seed oil can therefore be used as fuel in diesel engines.

Acknowledgements

This study was supported by Jomo Kenyatta University of Agriculture through the Research Production and Extension Department (RPE). Some fuel properties were measured at Kenya Bureau of Standards (KEBS). All are greatly acknowledged.

References

Deere, J. (1985). Fundamentals of service manual: Fuels, lubricants, and coolants. Deere and company, Illinois, USA. pp 1-25.

Kiss, A., Dimian, A., and Rothenberg, G. (2005). Solid Acid Catalysts for Biodiesel Production Towards Sustainable Energy. *Adv. Synth. Catal.,* **348**, PP 75–81.

Gunstone, F. D. (2004). The Chemistry of Oils and Fats: sources, composition, properties and uses. Blackwell Publishing Ltd, 9600 Garsington Road, Oxford OX4 2DQ, UK. pp 1-35.

Nyanzi, S. A., Carstensen, B. and Schwack, W. A Comparative study of fatty acids profiles of *Passiflora* seed oils from Uganda. *Journal of the American Oil chemists' Society*, **82**(1), pp 41-44.

Pinto, A. C., Guarieiro , L., Rezende, M. J., Ribeiro, N. M., Ednildo A.Torres, E. A., Lopes, A. W., Pereira, A. W. and Andrade J. B. (2005). Biodiesel: An Overview. *J. Braz. Chem. Soc.*, **16**(6B), pp 1313-1330.

Vincente, G., Martinez, M. and Aracil, J. (2004). Intergrated biodiesel production:A comparison of different homogenous catalysts systems. *Bioresource Technology*, **92,** pp 297-305.

Van Gerpen, J., Shanks, B., Pruszko, R., Clements, D. and Knothe, G. (2004).Subcontractor Report .August 2002–January 2004.Biodiesel Production Technology. National Renewable Energy Laboratory. pp 1-52.

OPTIMIZATION OF BIODIESEL PRODUCTION FROM COTTON SEED OIL USING KOH AND NAOH AS CATALYSTS

S .N. Mirie[1], G. T. Thiongo[2], P. N. Kioni[3], P. N. Kariuki[3] and W. S. Namaru[4]

[1,2]Department of Chemistry, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya

[3]Kimathi University College of Technology, Nyeri, Kenya

[4]Kenya Bureau of Standards, Nairobi, Kenya

Abstract

Biodiesel is commonly produced by the transesterification of plant oil or animal fat with short chain alcohols. This biomass fuel has received much attention, since it is a kind of alternative, biodegradable, nontoxic, and renewable energy source. It can be used as an alternative fuel in diesel engines with little or no modification in blended or neat form depending on the source of biodiesel. In this study transesterification reactions using cotton seed oil and methanol were performed using NaOH and KOH as catalysts so as to compare the two catalysts and also obtain the optimum reaction parameters which include temperature, and amount of alcohol. The reactions were optimized by varying the amount of methanol and the temperature. The optimum conditions when using KOH as a catalyst were obtained when using 150 % excess methanol at room temperature. Biodiesel of viscosity 4.27 mm^2/s, acid value 0.26 mgKOH/g and a yield of 83.94 % was obtained The optimum conditions when using NaOH as a catalyst were obtained when using 150% excess methanol and at temperature of 60^0C .The Biodiesel had a viscosity of 4.14 mm^2/s, acid value of 0.26 mgKOH/g and a yield of 68.60%.The best catalyst was found to be KOH as it gave higher yields under optimum conditions compared to NaOH. At optimum conditions for both catalysts, the fuel parameters measured were within range according to the American Society for Testing and Materials (ASTM) and International Standards Organization (ISO) test methods.

Key words: Biodiesel, transesterification, cottonseed oil, catalyst

1.0 Introduction

The predicated shortage of fossil fuel coupled with the increase in fuel prices has encouraged the research for other substitutes such as biodiesel. Biodiesel can be defined as the alkyl ester of fatty acids, made by the transesterification of oils or fats, from plants or animals, with short chain alcohols such as methanol and ethanol (Pinto *et al*., 2005).Biodiesel has advantages over conventional diesel in that it is safe ,renewable, non toxic and biodegradable It contains less sulphur compounds and a higher flash point (>130 ^{0}C).It has reduced Co_2 emissions and emits 80% fewer hydrocarbons and 50% less particles (Kiss *et al*).Biodiesel besides lowering the dependence on crude oil foreign exports ,it has a positive social impact by enhancing rural revitalization as farmers can grow vegetable oil crops and earn an income. The source for biodiesel production is chosen according to the availability in each region or country. With increasing prices of virgin, edible oils for fuel production there is a growing interest in alternative feedstocks including high-yielding non-edible tropical crops such as *Jatropha curcas*. On a longer term, oil from marine microalgae has been proposed. Algae have oil productivities (L/ha/year) that far exceed that of any land-based crops, which is needed for biofuels to fully meet global demand for transport fuels. Oils from different sources have different fatty acid compositions. The fatty acids are different in relation to the chain length, degree of unsaturation or presence of other chemical functions (Pinto *et al*., 2005). Catalysts that are used in the biodiesel making process may either be base, acid, or enzyme materials. Sodium hydroxide, potassium hydroxide and sodium methoxide are the most commonly used catalysts. Base catalyzed reactions are relatively fast, with residence times from about 5 minutes to about 1 hour, depending on temperature, concentration, mixing and alcohol: triglyceride ratio (Van Gerpen *et al*., (2004). Acid catalysts include sulfuric and phosphoric acids. Compared to base catalysts, acid catalysts reactions have been found to be too slow for industrial processing. Acid catalysts are however used to reduce the free fatty acids (FFA 'S) in crude vegetable oils having a high value and then the base catalyst is added in the second stage to convert the remaining triglycerides into biodiesel. In a study by Vincente *et al.,* (2004) transesterifcation of sunflower oil with methanol gave higher yields when using KOH as compared to when NaOH was used as catalyst. However their methoxide counterparts gave even higher yields because the yield losses due to triglyceride saponification and methyl ester dissolution in glycerol were negligible .The aim of this study was to produce biodiesel from cotton seed oil using KOH and NaOH and also make a comparison between the two catalysts. The optimum reaction parameters which include temperature, and amount of alcohol were also determined.

2.0 Materials and Methods

The reagents used were of analytical grade. Methanol, acetone and 2-propanol were purchased from Sigma (Seelze, Germany). The catalysts sodium hydroxide and potassium hydroxide were obtained from Rankem (New Delhi India). Toluene was obtained from Merck (Barcelona, Spain).Cotton seeds were obtained from farmers in Mwea, Kenya and their identity confirmed at the herbarium in botany department, Jomo Kenyatta University of Agriculture and Technology. A screw press (Ruian grain and oil machinery factory Zhejiang China) was used to obtain the oil from the seeds by pressing. The oil obtained from the screw press was first filtered slowly using filter bags then refiltered again using a vacuum pump to remove any scum and particles. Various crude oil properties were measured for the filtered vegetable oil. They included viscosity, acid value specific gravity and fatty acid profiling to establish the fatty acid compositions of the oils.

2.1 Fatty Acid Profiling

Fatty acid profiling was done to establish the fatty acid composition of the oil .For the chromatographic analysis cotton seed oil was converted to its corresponding methyl esters according to the method described by Stoffel *et al*., 1959. A shimadzu gas chromatograph (GC-9A) equipped with a flame ionization detector and fitted with a glass column (3mm x 1mm) packed with DEGS (Diethylene glycol succinate) was used for the analysis. The injection and detector

temperatures were set at 220 ^{0}C while the column temperature was set at 170 ^{0}C.The fatty acid methyl esters were identified with the help of standards purchased from Supelco (U.S.A).

2.2 Determination of Acid Value

The acid value for the vegetable oil was determined by the method described by Van Gerpen *et al*., 2004. Two 250ml beakers were prepared by adding 62.5ml of solvent .The solvent consisted of 50% isopropyl alcohol and 50% toluene.2.5g of the crude vegetable oil was added to one of the beakers (sample beaker) and the other beaker left with out a sample (blank beaker). Both beakers were titrated with 0.1N KOH to the first permanent pink color using 2ml of phenolphthalein as an indicator in each. The procedure was done in triplicate and the average obtained. The acid value was calculated using the equation,

A.V = (A-B) ×N×56.1/W where,

A= Number of ml of KOH needed to neutralize sample beaker, B=Number of ml of KOH needed to neutralize blank beaker, N=Normality of KOH solution, W =Weight in gram of sample used and % F.F.A =1/2 Acid value.

2.3 Determination of Viscosity

The kinematic viscosity was measured using a capillary viscometer (viscometer no. 38, Kusano Scientific Instrument) immersed in a water bath maintained at 40^{o}C and 10ml of the sample placed in the viscometer .The flow of the sample between two marked points on the viscometer under gravity was recorded. Three readings were taken and the average obtained. The timings of 10ml of water were also recorded. The viscosity was measured according to the equation;

$$\text{Viscosity (Centipoises)} = \frac{\text{Time taken for vegetable oil to flow (seconds)}}{\text{Time taken for water to flow (seconds)}} \times 0.65$$

Where 0.65 =Dynamic viscosity of water at 40^{o}C and

Viscosity in centistokes = Viscosity in centipoises at 40^{o}C **/** Specific gravity at 40^{o}C

2.4 Determination of Specific Gravity

The specific gravity of the oil was measured using a pycnometer. A clean and dry pycnometer of 25ml capacity was weighed (W_0) with the help of an analytical balance and then filled with the sample. The stoppers were then inserted and the pycnometer reweighed to give (W_1). The sample was substituted with water after washing and drying the bottle and reweighed to give (W_2). The expression for specific gravity (Sp.gr) is:

Sp.gr = (W_1-W_0)/ (W_2-W_0) = Mass of the substance / Mass of an equal volume of water.

To get the specific gravity at 40^{o}C the pycnometer was placed in a water bath to attain the required temperature

2.5 Transesterification Reactions with KOH and NaOH

Transesterification reactions of cotton seed oil with KOH and NaOH were done with the help of a hot plate magnetic stirrer (Autoscience AM-5250B, Tianjin Instrument Co. Ltd.) capable of maintaining the required temperature. The reactions were done by varying the amount of methanol and reaction temperature while keeping the catalyst amount at a constant**.** The amounts of KOH and NaOH to use for the experiments were calculated according to Van Gerpen *et al*., 2004. 91.35g (100ml) of cotton seed oil with a % FFA of 5.67 required 1.66g of NaOH while 1.93g of KOH was required for the reactions. The amount of methanol was varied by using between 0-150 % excess methanol of the stoichiometric amount required for a complete transesterification reaction. The reactions were first done at room temperature (25^0 C) and some of the reactions repeated at 40^0 C and 60 ^{0}C with the various amounts of methanol. The catalysts (KOH and NaOH) were first dissolved in the appropriate amount of methanol and then added to the vegetable oil contained in a separate conical flask having a magnetic rod placed inside. The flask was then placed in the hot plate and the mixture was stirred

at a rate of 700rpm for 2hrs .For the reactions at room temperature the flask was stoppered while for the reactions at 40^0 C and 60^0 C the flask was fitted with a condenser then, stirred and refluxed continuously for 2hrs. The mixture was then left overnight to settle in a separating funnel .After settling, the mixture separated into two phases, the lower part being glycerin and the upper part the ester layer. The glycerin was then allowed to come out by opening the tap on the separating funnel in order to remain with the ester layer. A vacuum rotary evaporator set at 65^0C was then used to remove any excess methanol left. The ester layer was washed by placing it in a separating funnel and spraying warm water (40^oC) representing a quarter amount of the biodiesel being washed using a spraying can and removing the water at the bottom of the funnel. This was done until the wash water did not turn pink on addition of phenolphthalein indicator, indicating that the catalyst was washed out. The ester layer was dried after washing by heating the layer at 60^0C in a beaker until the layer changed from being cloudy to clear indicating that the water had been evaporated. For the reactions at 40^0 C and 60 ^{0}C the magnetic stirrer was set at those temperatures and the same process repeated. The % yield from the reactions was obtained by dividing the weight of biodiesel obtained with the initial weight of the vegetable oil started with. Other parameters measured after obtaining the biodiesel are viscosity, specific gravity and acid value. All the reactions were done in triplicate and average values recorded.

2.5 Other Fuel Properties Measurement

The determination of other fuel properties was done at Kenya Bureau of Standards (KEBS), Nairobi using ISO, and ASTM test methods.

3.0 Results

3.1 Crude Vegetable Oil Properties

The fatty acid composition for cotton seed oil is shown in Table 1 and is compared with literature values (Pinto *et al*., 2005), while Figure 1 shows the fatty acid methylester profile of cotton seed oil obtained from the GC. Linoleic acid (50.3%) was found to be the major fatty acid in cotton seed oil followed by palmitic acid (26.2%). This is supported by Gunstone, (2004), who states that "cotton seed is unique among the commodity vegetable oils in that it contains a relatively high level of palmitic acid while linolenic acid is virtually absent."

Table 1: Fatty acid composition of cotton seed oil

Fatty acid	*Composition (%)*	*Literature values (%) (Pinto et al., 2005)*
Myristic acid (C14:0)	0.8	-
Palmitic acid (C16:0)	26.2	28.6
Stearic acid (C18:0)	2.1	0.9
Oleic acid (C18:1)	19.7	13.0
Linoleic acid (C18:2)	50.3	57.2
Others	0.9	0.3

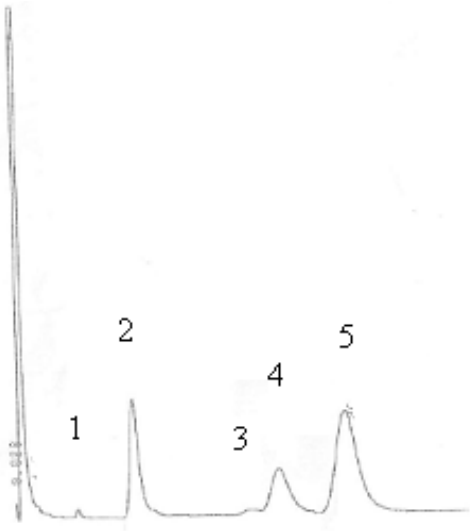


Figure 1: Fatty acid methyl ester profile of cotton seed oil

Peak assignment: 1= C14:0, 2= C16:0, 3 = C18:0, 4 = C18:1, and 5 = (C18:3) methylesters.

The acid value of the oil was found to be 11.3 and % FFA 5.6 (Acid value/2). The viscosity of the oil was found to be 32.57 centistokes and had a specific gravity of 0.9210.

3.2 Reactions with KOH

Experiments with cotton seed oil and KOH were first performed at room temperature and the reactions at 100% and 150% excess methanol were then repeated at 40^0 C and 60 ^{0}C as there were the most promising considering the yield and viscosity. Table 2 shows the reactions at room temperature, table 3 reactions at 40^0 C while table 4 shows reactions at 60 ^{0}C.

Table 2: Reactions with KOH at room temperature

Property	ASTM D 6751 – 02 Requirements	0% excess methanol	25% excess methanol	50 % excess methanol	75 % excess methanol	100% excess methanol	150% excess methanol
% Yield	-	78.03 ± 0.72	81.54 ± 1.50	83.75± 1.05	83.82 ± 0.81	83.92 ± 0.33	83.94 ± 1.34
Specific gravity (40^oC)	0.88 (25^oC)	0.8879± 0.0020	0.8776± 0.0032	0.8803± 0.0024	0.8788± 0.0002	0.8755± 0.0024	0.8760± 0.0017
Viscosity (mm^2/s) (40^oC)	1-6	7.16 ± 0.15	5.80 ± 0.08	5.07 ± 0.10	4.83 ± 0.13	4.35 ± 0.06	4.27± 0.09
Acid value (mg KOH/g)	Max 0.8	0.36± 0.04	0.26± 0.07	0.26 ± 0.07	0.26 ± 0.07	0.26 ± 0.07	0.26 ± 0.03

Table 3: Reactions with KOH at 40 ^{o}C

Property	*ASTM D 6751 – 02 Requirements*	*100% excess methanol*	*150% excess methanol*
% Yield	-	83.27 ± 0.4	83.70 ± 0.39
Specific gravity ($40^{o}C$)	0.88 ($25^{o}C$)	0.8771 ± 0.0004	0.8790 ± 0.0009
Viscosity (mm^2/s) ($40^{o}C$)	1-6	4.63 ± 0.06	4.39 ± 0.01
Acid value (mg KOH/g)	Max 0.8	0.26 ± 0.05	0.26 ± 0.03

Table 4: Reactions with KOH at 60 ^{o}C

Property	*ASTM D 6751 – 02 Requirements*	*100% excess methanol*	*150% excess methanol*
% Yield	-	83.03±0.55	83.12 ± 0.91
Specific gravity ($40^{o}C$)	0.88 ($25^{o}C$)	0.8753±0.0024	0.8753±0.0022
Viscosity (mm^2/s) ($40^{o}C$)	1-6	4.18 ± 0.09	4.08 ± 0.01
Acid value (mg KOH/g)	Max 0.8	0.26±0.03	0.26 ± 0.04

3.2.1 Discussion

The highest yield obtained from the reactions of cotton seed oil and KOH as a catalyst was 83.94% and it was obtained when using 150% excess methanol and room temperature (Table 2). The lowest yield was 78.03% and it was obtained when using 0% excess methanol (Table 2). The yield (78.0355%) however is misleading as the biodiesel has a high viscosity (7.1561mm^2/s) which was out of the required range according to ASTM standards ,indicating that the mixture probably contains some amount of triglycerides, monoglycerides and triglycerides in addition to methyl esters.100% yields were not obtained in the experiments and this can be attributed to the free fatty acids in the initial vegetable oil which were 5.67% of the total weight of the vegetable oil .The maximum yield possible from the experiments is 94.33% for 100% yield for the reaction as 5.67% are free fatty acids. The reactions using more than 0% excess methanol gave biodiesel with viscosities within range according to ASTM standards. The repeated reactions at 40^{0} C and 60 ^{0}C did not show any signifiacant increase in the biodiesel obtained and they recorded a slight decrease in the yields .The acid values for all the experiments were within range according to ASTM standards.

3.3 Reactions with NaOH

Experiments with cotton seed oil and NaOH were first performed at room temperature and then the reactions at 100% and 150% excess methanol repeated at 40^0 C and 60 ^{0}C as there were the most promising considering the yield and viscosity. Table 5 shows the reactions at room temperature, table 6 reactions at 40^0 C while table 7 shows reactions at 60 ^{0}C.

Table 5: Reactions with NaOH at room temperature

Property	*ASTM D 6751 – 02 Requirements*	*75% excess methanol*	*100% excess methanol*	*150% excess methanol*
% Yield	-	43.65 ± 0.27	49.18 ± 0.91	60.56 ± 0.77
Specific gravity (40^oC)	0.88 (25^oC)	0.8795±0.0042	0.8761±0.0029	0.8760± 0.0040
Viscosity (mm^2/s) (40^oC)	1-6	4.61 ± 0.06	4.16 ± 0.09	4.08± 0.19
Acid value (mg KOH/g)	Max 0.8	0.26±0.07	0.26 ± 0.03	0.26±0.07

Table 6: Reactions with NaOH at 40 ^oC

Property	*ASTM D 6751 – 02 Requirements*	*100% excess methanol*	*150% excess methanol*
% Yield	-	65.31± 0.7	65.47± 0.99
Specific gravity (40^oC)	0.88 (25^oC)	0.8733± 0.0010	0.8741± 0.0018
Viscosity (mm^2/s) (40^oC)	1-6	4.41±0.01	4.33± 0.09
Acid value (mg KOH/g)	Max 0.8	0.36±0.07	0.30 ± 0.07

Table 7: Reactions with NaOH at 60 ^oC

Property	*ASTM D 6751 – 02 Requirements*	*100% excess methanol*	*150% excess methanol*
% Yield	-	68.32 ± 1.01	68.60 ±1.67
Specific gravity (40^oC)	0.88 (25^oC)	0.8739± 0.0017	0.8748± 0.0010
Viscosity (mm^2/s) (40^oC)	1-6	4.14 ± 0.03	4.14± 0.06
Acid value (mg KOH/g)	Max 0.8	0.26 ± 0.26	0.26 ± 0.03

3.3.1 Discussion

The highest yield obtained with transesterification of cotton seed oil with NaOH as catalyst was 68.60 % and was obtained when using 150% excess methanol and a temperature of 60 ^{o}C (Table 7). An increase in temperature of the reaction resulted to some significant increase in the biodiesel yield. The viscosity and acid values for the experiments were within range according to ASTM standards. Generally the yields when using NaOH as catalyst were lower than when KOH was used as catalyst.

3.4 Results for other Fuel Properties Measurements

More biodiesel properties were measured for the best catalyst and the best condition, namely, the biodiesel from transesterification of cotton seed oil with KOH, 150% excess methanol and room temperature. The results are shown in Table 8.

Table 8: Other fuel properties measurement

Property	*Method*	*Apparatus*	*limits*	*CSEK*
Density @ 20^{o}C (kg/m^{3})	ISO 12937	S.G density meter (DMA 4500)	860-900	881
Kinematic viscosity at 40^{0}c (mm^{2}/s)	ISO 3104	Automatic viscometer (HMV 472 HERZOG)	3.5-5.0	4.32
Astm colour	ASTMD 1500	Tintometer (Lovibond PFX880)	Max 3.5	3.3
Copper strip corrosion (3h at 50^{0}c rating, Max)	ISO 2160	Air oven, (Memmert)	Class 1	No tarnish
Density @15 ^{o}C (kg/ m^{3})	ISO 12185	Density meter (DMA4500)	860-900	885
Flash point ^{o}C, min	ASTMD 93	Pensky Martens closed cup tester	130 min	>150

CSEK= Biodiesel from transesterification of cotton seed oil with KOH, 150% excess methanol and room temperature.

The results show that the process of transesterification greatly reduces the viscosity as the initial viscosity of the oil was 32.57 centistokes but after transesterification with KOH and 150% excess methanol at room temperature the viscosity fell to 4.32 centistokes. This leads to improved fuel properties of the cotton seed oil. The flash point for the biodiesel is above 150^{0}C hence it safe to use as there is no risk of explosion .The high flash point also shows that there is no residual alcohol remaining in the fuel. It can be seen from the results that the biodiesel is not corrosive to copper indicating very little effect on corrosion of the engine. All the other properties measured which include kinematic viscosity, density and Astm colour meet the given standard.

4.0 Conclusion and Future Perspective

Experiments with KOH and NaOH with cotton seed oil were successful as the biodiesel obtained at optimum conditions meet the standards .The biodiesel obtained from the above process can therefore be used successfully as fuel. Experiments with KOH generally gave higher yields than experiments with NaOH. This is well in agreement with Vincente *et al* 2004, where experiments with KOH gave higher yields than those with NaOH when using sunflower oil as the vegetable oil. Near 100% yields were not obtained and this can be attributed to saponification as the cotton seed oil had % FFA of 5.8.

Acknowledgements
This study was supported by Jomo Kenyatta University of Agriculture through the Research Production and Extension Department (RPE).Some fuel properties were measured at Kenya Bureau of Standards (KEBS). All are greatly acknowledged.

References

Bligh, E. G. and Dyer, W. J. A. (1959). A rapid method for total lipid extraction and purification. *An.J.Biochem and Physiol*., **37**, pp 911-917.

Deere, J. (1985). Fundamentals of service manual: Fuels, lubricants, and coolants. Deere and company, Illinois, USA .pp 1-25.

Kiss, A., Dimian, A., and Rothenberg, G. (2005). Solid Acid Catalysts for Biodiesel Production Towards Sustainable Energy. *Adv. Synth. Catal.,* **348**, pp 75–81.

Gunstone, F. D. (2004). The Chemistry of Oils and Fats: sources, composition, properties and uses. Blackwell Publishing Ltd, 9600 Garsington Road, Oxford OX4 2DQ, UK. pp1-35.

Knothe, G. (1999). Rapid monitoring of transesterification assessing biodiesel quality by NIR spectroscopy using a fiber-optic probe. *J. Am. oil Chem .Soc.,* **76**(7), pp 795-800.

Lee, D. H., Kim, J. M., Shin, H. Y., Kang, S. W. and Kim, S. W. (2006). Biodiesel production using a mixture of immobilized *Rhizopus oryzae* and *Candida rugosa* lipases. *Biotechnol Bioprocess Eng.*, **11**, pp 522–525.

Pinto, A. C., Guarieiro , L., Rezende, M. J., Ribeiro, N. M., Ednildo A.Torres, E. A., Lopes, A. W., Pereira, A. W. and Andrade J. B. (2005). Biodiesel: An Overview. *J. Braz. Chem. Soc*., **16**(6B), pp 1313-1330.

Vincente,G., Martinez, M. and Aracil, J. (2004). Intergrated biodiesel production: A comparison of different homogenous catalysts systems. *Bioresource Technology*, **92,** pp 297-305.

Stoffel, W, Chu,F. and Ahrens, E. H. (1959). Analysis of long chain fatty acids by gas-liquid chromatography :Micromethod for preparation of methyl esters. *Anal.Chem.,* **31**, pp 307-

Van Gerpen, J., Shanks, B., Pruszko, R., Clements, D. and Knothe, G. (2004). Subcontractor Report .August 2002–January 2004.Biodiesel Production Technology. National Renewable Energy Laboratory. pp 1-52.

APPLICATION OF RENEWABLE ENERGIES FOR STORAGE OF HORTICULTURAL PRODUCE IN MARGINAL AREAS OF KENYA

J. T. Makanga[1], D. Shitanda[2], C. Njoroge[3] and M.G. Ong'era[4]

[1,2,4]Biomechanical and Environmental Engineering Department, College of Engineering and Technology, Jomo Kenyatta University of Agriculture and Technology, Nairobi

[3]Food Science and Postharvest Technology Department, Faculty of Agriculture, Jomo Kenyatta University of Agriculture and Technology, Nairobi

E-mail: jamesmakanga@yahoo.com

Abstract

The objective of the research were to a prototype solar-charcoal cooler and test its performance in the temperature development and products storageability. A prototype solar-charcoal cooler was developed at the Biomechanical and Environmental Engineering Department (BEED), College of Engineering and Technology of the Jomo Kenyatta University of Agriculture and Technology (JKUAT), Kenya and performance tested in terms of temperature and product storageability. The performance of the cooler indicated positive results as regards to ideal parameters affecting produce storage. These parameters mainly included variations in temperature and humidity to levels ideal to product storage. The results also indicated that various fruits and vegetables including paw paws and spinach could be stored in the cooler for longer periods as compared to when they were under ambient conditions.

Key words: Renewable, energies, storage, horticultural, produce, solar-charcoal, cooler

1.0 Introduction

As the case is with many developing countries, Kenya relies heavily on agriculture for food and employment particularly in the rural areas. Attempts in ensuring high productivity in agriculture should hence be encouraged. Horticultural crops have steadily gained importance in foreign exchange earnings such that the sector is now the second foreign exchange earner after tea. There are however, some serious challenges the sector is facing including lack of ideal facilities for proper storage of perishables and semi-perishables at the farm level in Kenya and in particular between harvesting and the time when the crop is accepted by the customer. This has resulted in tremendous losses and loss of morale for the farmers. Simple and effective storage systems should therefore be developed and used to minimize losses thus improving the net returns on farmers.

Various methods for handling and processing farm produce are used in several parts of the world. Refrigeration plays an important role in developing countries, particularly for the preservation of food, medicine and for air conditioning. Cooling can be provided in different ways. The method adopted in industrialized countries depends heavily on grid electricity supplied continuously and reliably to every part of the country. In contrast, refrigeration is required in developing countries to stimulate agriculture and commerce in vast areas without a reliable electricity supply. Less than 20% of the Kenyan population has access to electricity thus making it not only impossible but also expensive to use cold storage systems at the rural level. Alternative methods are therefore necessary.

Currently more effort is being directed towards the production and marketing of raw produce. However, little emphasis has been put on the storage, processing and local use of such produce (ITDG, 2005). Storage helps to maintain quality and is part of orderly marketing. Storage also ensures continuous supply of similar quality produce during off-season. Other reasons for storage include; handling of over-production, sustainability and continuity of farm operations, (Bakker-Arkema, 1999).

The charcoal cooler has been in use for ages but its adaptability in Kenya has been poor due to lack of construction standards and scientific back-up on its performance potentials. This paper reports the performance of a solar-charcoal cooler which mainly in temperatures, humidity and products.

2.0 Materials and Methodology

The prototype solar-charcoal cooler used in this study was developed at the Biomechanical and Environmental Engineering Department, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya. It was made of a mild steel frame covered in wire mesh on the outside and lined with an aluminium sheet on the inside. The cooler mainly comprised of two components namely the solar air drift and a cooling chamber. The solar air drift has it main components in a solar panel and a battery to store solar energy as electricity. The electrical power was used to drive a fan which blew or drew air through the charcoal to facilitate evaporation of water from the charcoal. The cooling chamber was lined with aluminium sheet on the inside, charcoal layer on the outside and a water pan at the top for water supply. Figure 1 shows a pictorial presentation of the solar-charcoal cooler.

Figure 1: The prototype solar-charcoal cooler developed for laboratory studies

Initial performance tests of the cooler involved monitoring of the temperatures and relative humidity values in and out of the cooler over a 24 hour period for about one month. Some farm produce namely paw paws, tomatoes, bananas, carrots, cabbage, kales and spinach were then stored in the cooler till the end of their shelf life and their storageability evaluated with time. The tests carried out to evaluate storageability included firmness, vitamin C (ascorbic acid), starch, colour and weight tests.

Firmness tests on the fruits and colour tests on all the products were carried out after three days intervals for 14 days by use of a fruit firmness tester also known as a pressure tester or penetrometer. Firmness or crispness is used as a test for suitability for consumption. The materials and equipment for starch tests included iodine solution, vegetable leaves to be tested, a large test tube sometimes called a boiling tube, a 250 ml glass beaker, ethanol and a teat pipette. The glass beaker was filled to half with boiling water and a large test tube which was a quarter full of ethanol

added to it. The ethanol was allowed to boil. The leaf to be tested was softened in the boiling water for ten seconds and then added to the ethanol and allowed to boil for a minute until all its colour disappeared. It was then removed from the ethanol and put back in the hot water to soften for ten seconds thereafter spread on a white tile and three drops of iodine solution dropped on it to test for starch. A blue-black colour would indicate the presence of starch.

Loss of colour and shrinkage of agricultural produce plays a vital role in consumer/customer attraction and enhances product acceptability. Shrunk products with undesirable colour will not appeal to consumers. Loss of colour and shrinkage was determined by physical/visual inspection. Handling and storage are among the factors that affect vitamin C contents of fresh produce. The retention of vitamin C is often used as an estimate for the overall nutrient retention of food products because it is by far the least stable nutrient. It is highly sensitive to oxidation and leaching into water-soluble media during storage. The materials and equipment used for vitamin C tests in this study included 1% starch indicator solution, iodine solution, a graduated cylinder, 250 ml glass beaker, 100 ml conical flask and a teat pipette. The fruits were first thoroughly washed and their juices extracted by mechanical pressure. Each type of juice sample was filtered to remove pulp and seeds and placed in labeled plastic containers. The juices were then transferred into the 100 ml conical flask and ten drops of starch solution added. This was then titrated with the iodine solution until the first blue colour which persisted for about twenty seconds was observed. The initial and final volume of iodine solution required to produce the colour change at the end point was recorded. Increases in pH values of the fruit juices as time goes by is related to the deterioration of fruit characteristics. Weight tests were conducted since fresh fruits and vegetables contain a lot of water. Water loss results into loss of weight (saleable weight) and that constitutes a direct loss in marketing. Measures that minimize water loss after harvesting will thus enhance profitability. A loss of 5% of the weight will usually make products appear wilted or shriveled.

3.0 Results and Discussion

The observations of this study indicated that applications of charcoal and solar energy can yield positive results in improving storageability of horticultural produce. Improvement in temperature and relative humidity which are sensitive parameters as regards to produce storegeability was observed. This is shown on figures 2-7. The relative humidity generally increased with the use of wet charcoal. However, when the fan was used the humidity decreased implying that a combination of the charcoal wetting and fan utilization would result in ideal storage conditions. Ambient temperatures were higher as compared to those in the charcoal cooler particularly when charcoal wetting was involved. The results did not indicate major effect on temperature when the fan was used. However, temperatures in the cooler seemed to be more uniform which might be an ideal situation for some produce stored in the cooler.

The various tests conducted to evaluate storegeability of the produce also indicated positive results when the solar-charcoal cooler technology was involved. Figures 8 and 9 show the observations for fruit firmness tests. Results for starch tests on vegetables are shown on tables 1 and 2. Again in this case, a combination of charcoal cooling and solar energy utilization result in improved performance. Results for vitamin C tests on fruits as presented on tables 3 and 4 also indicated less increases in pH values when solar energy technology was used as compared to when only charcoal was used. Increases in pH values of the fruit juices where only charcoal cooling was used was related to deterioration of fruit characteristics. Observations for weight tests as shown on tables 5 and 6 again indicated that the use of the solar technology improved storageability due to reduced water loss, i.e, reduced weight losses. Results of tests carried out to investigate the effects on shrinkage and loss of colour are presented on tables 7 and 8. The use of the solar energy, i.e,use of the solar power driven fan indicated some positive improvement on some produce.

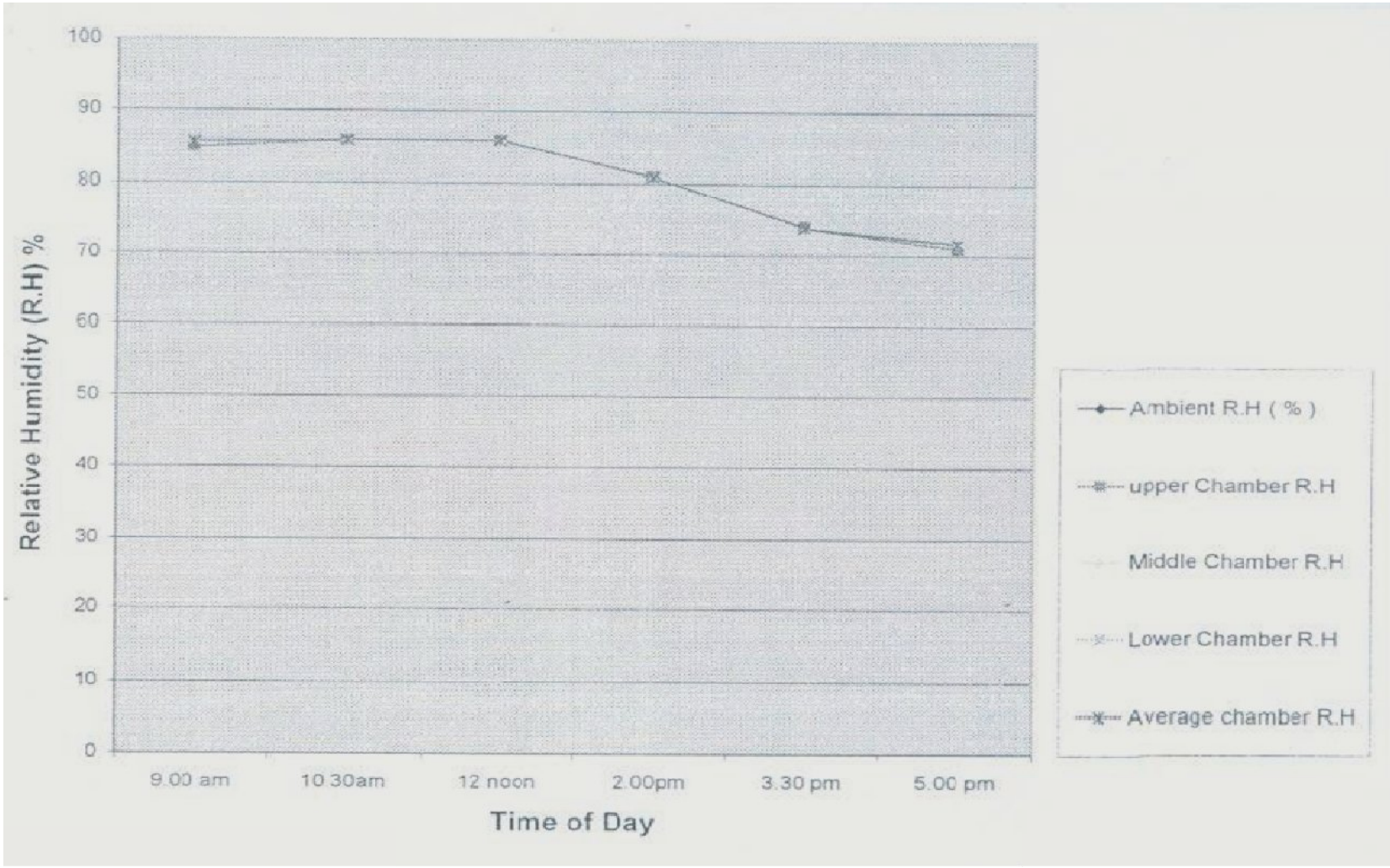


Figure 2: Relative humidity variation with time (before charcoal wetting and fan was off)

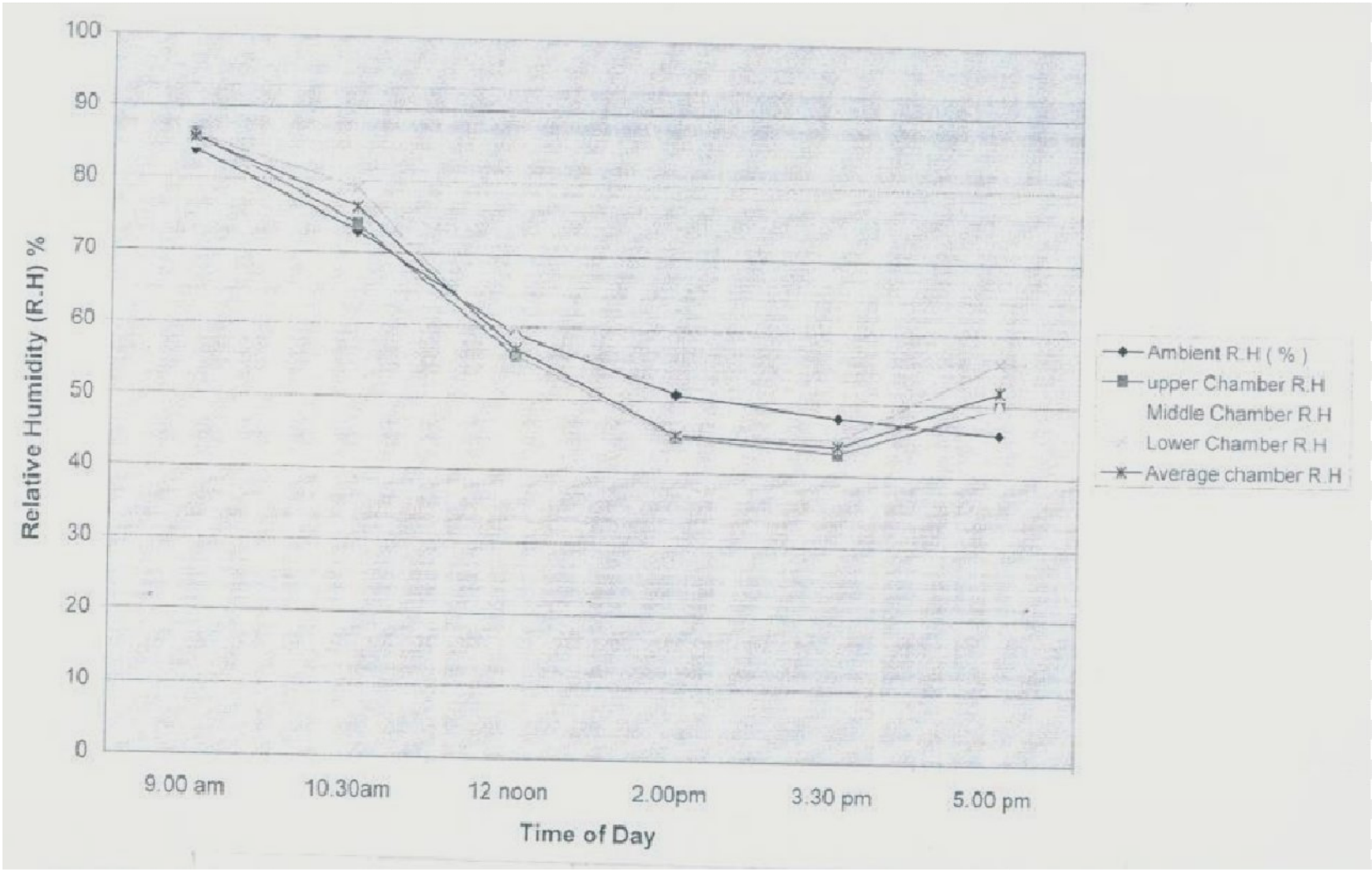


Figure 3: Relative humidity variation with time (after charcoal wetting and fan was off)

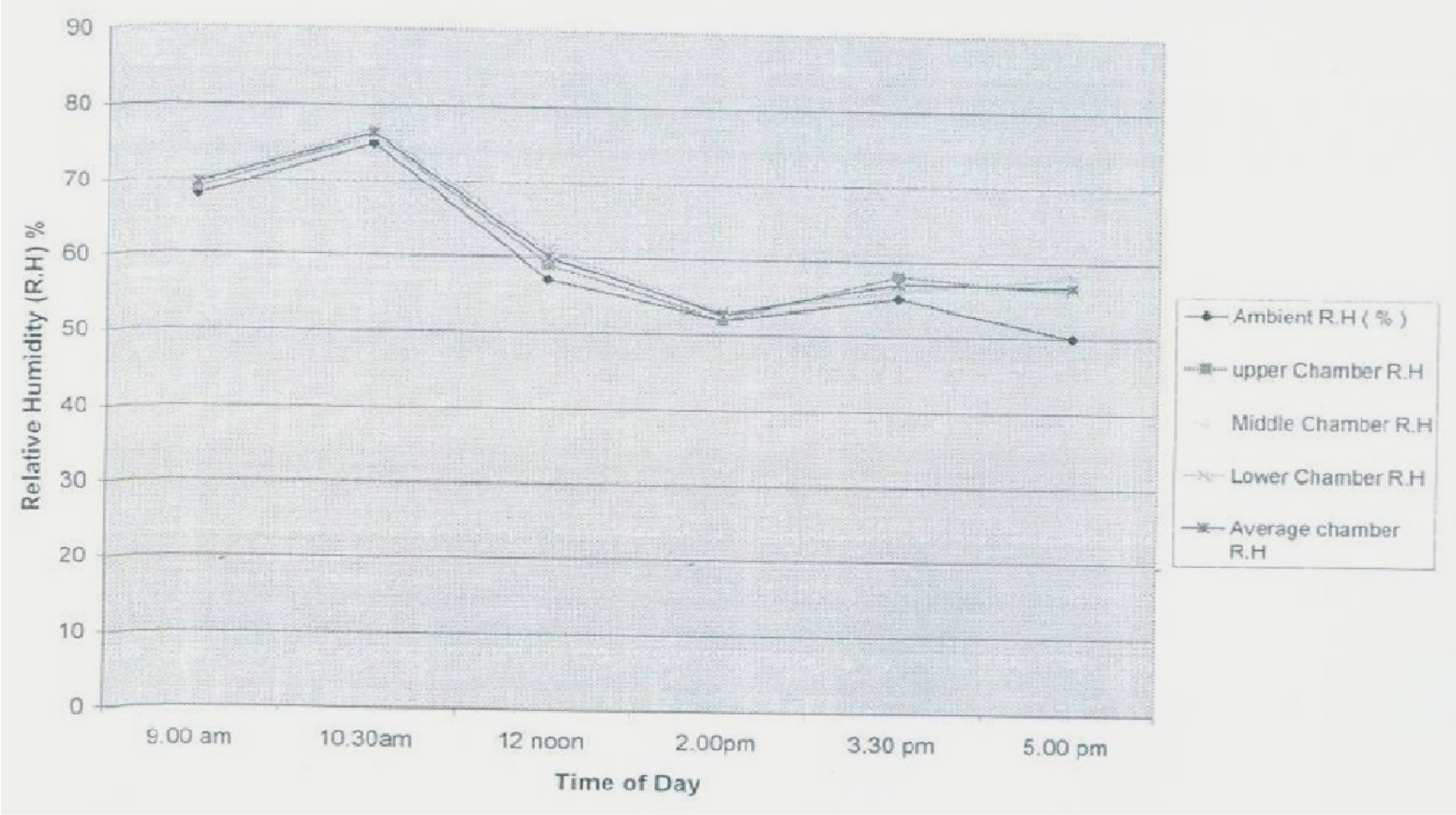


Figure 4: Relative humidity variation with time (after charcoal wetting and fan was on)

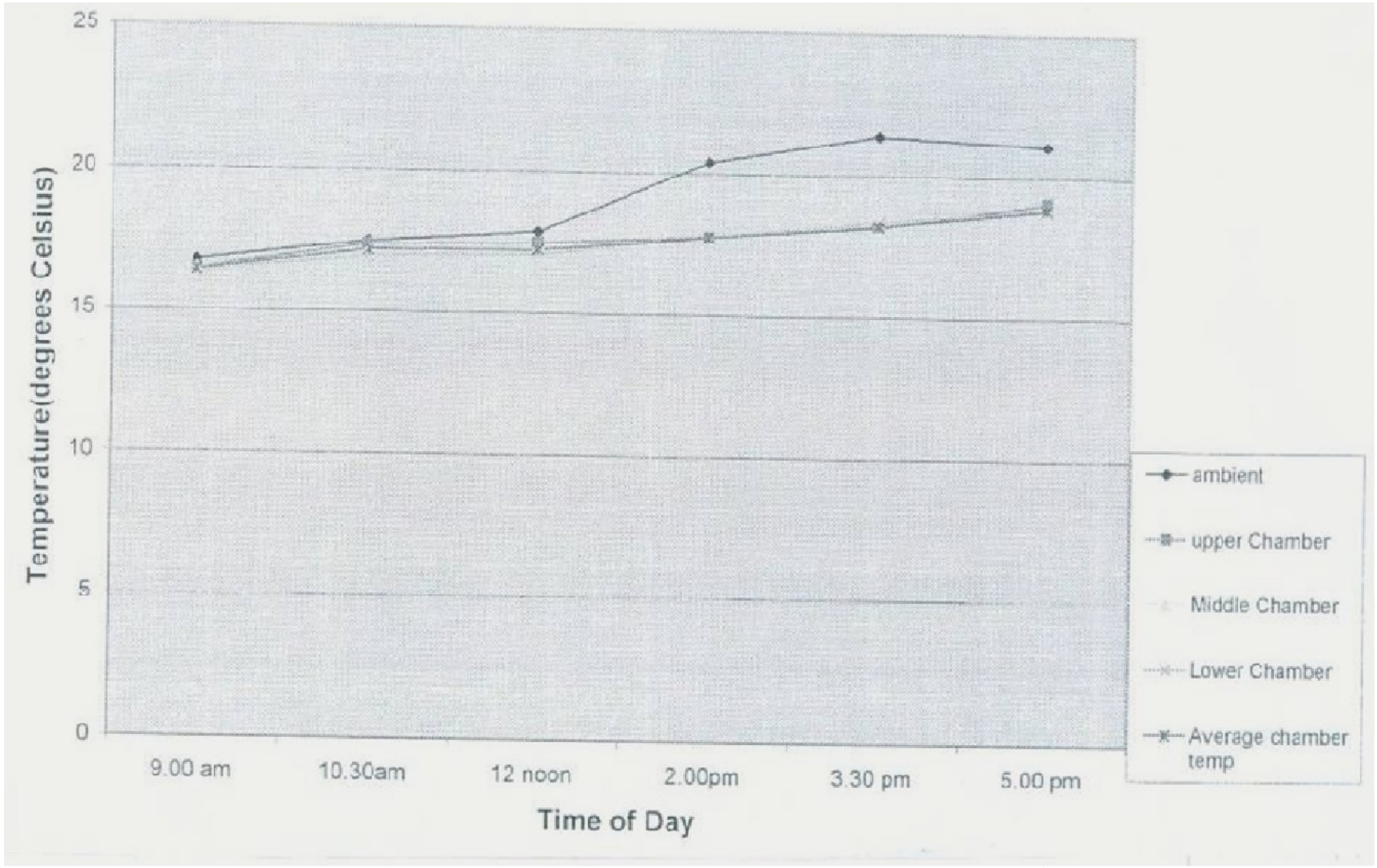


Figure 5: Temperature variation with time (before charcoal wetting and fan was off)

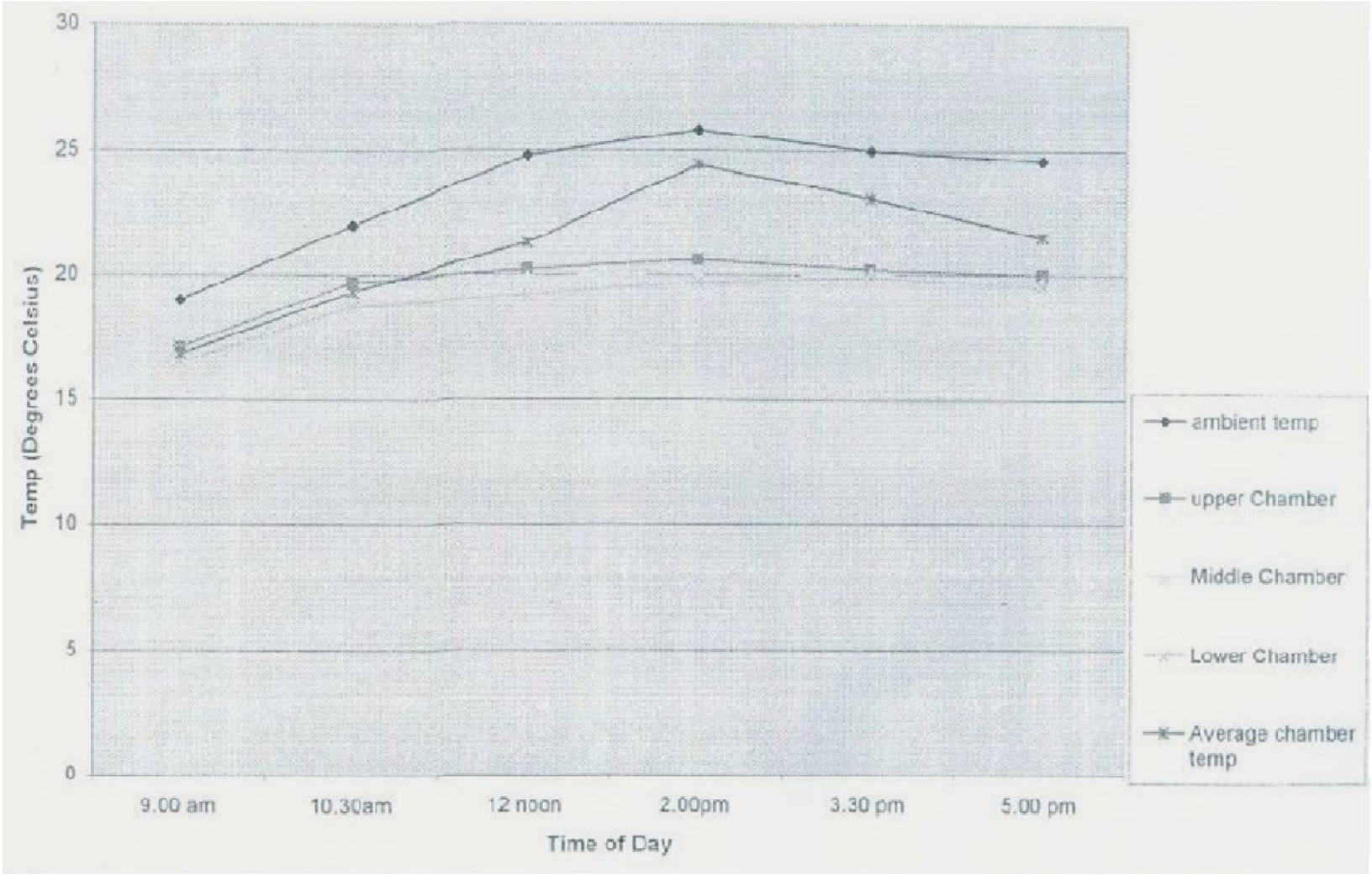


Figure 6: Temperature variation with time (after charcoal wetting and fan was off)

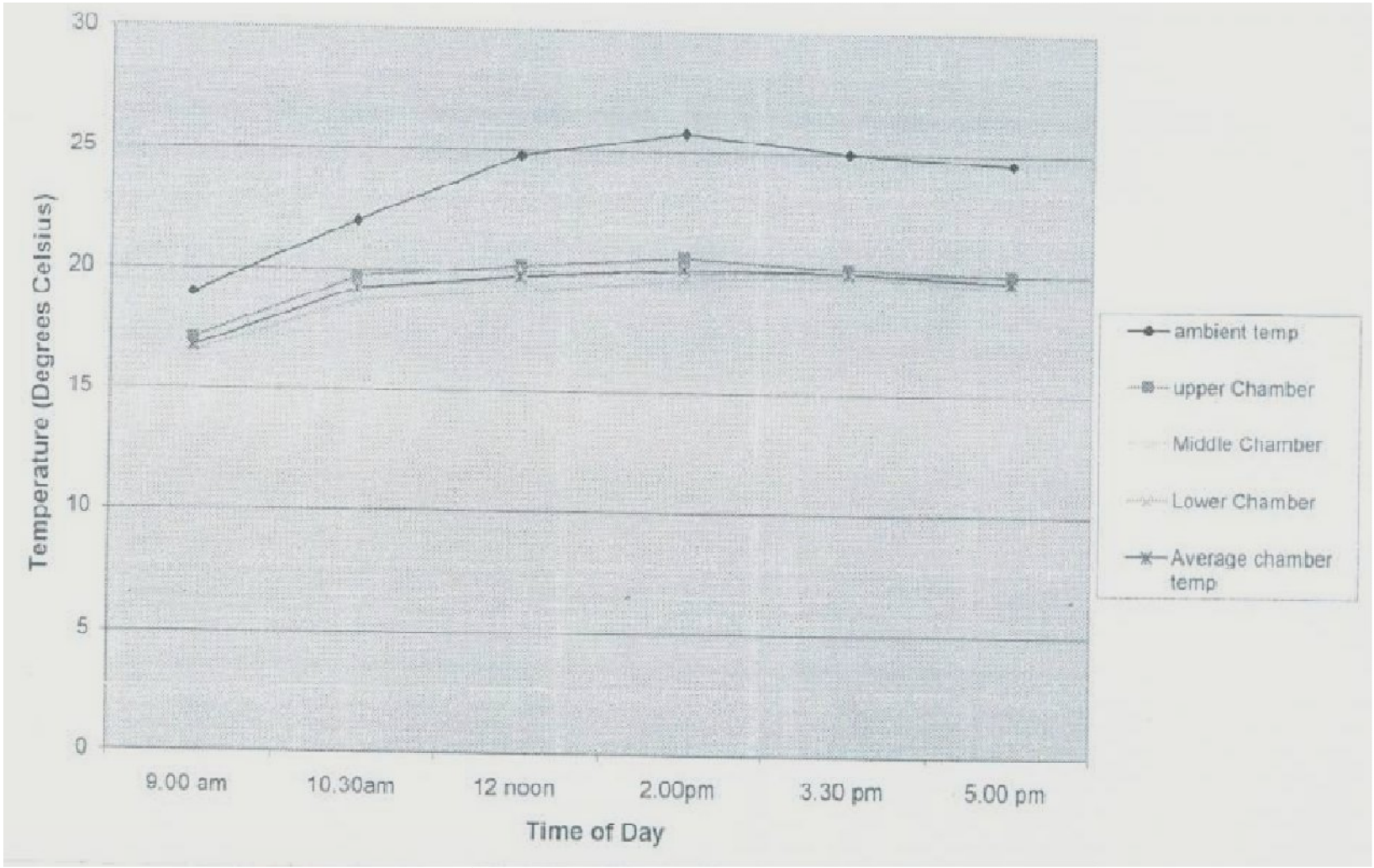
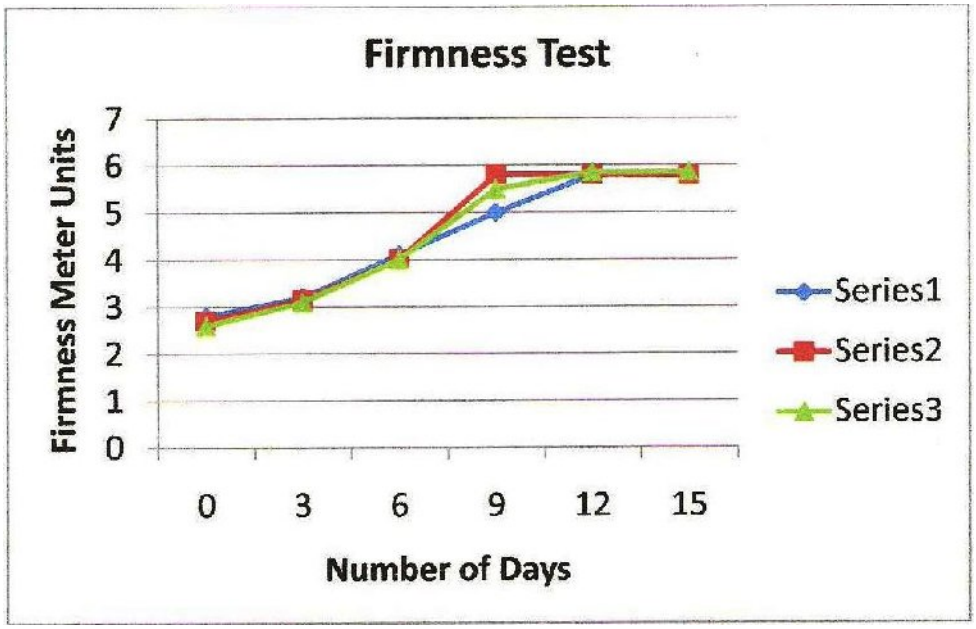
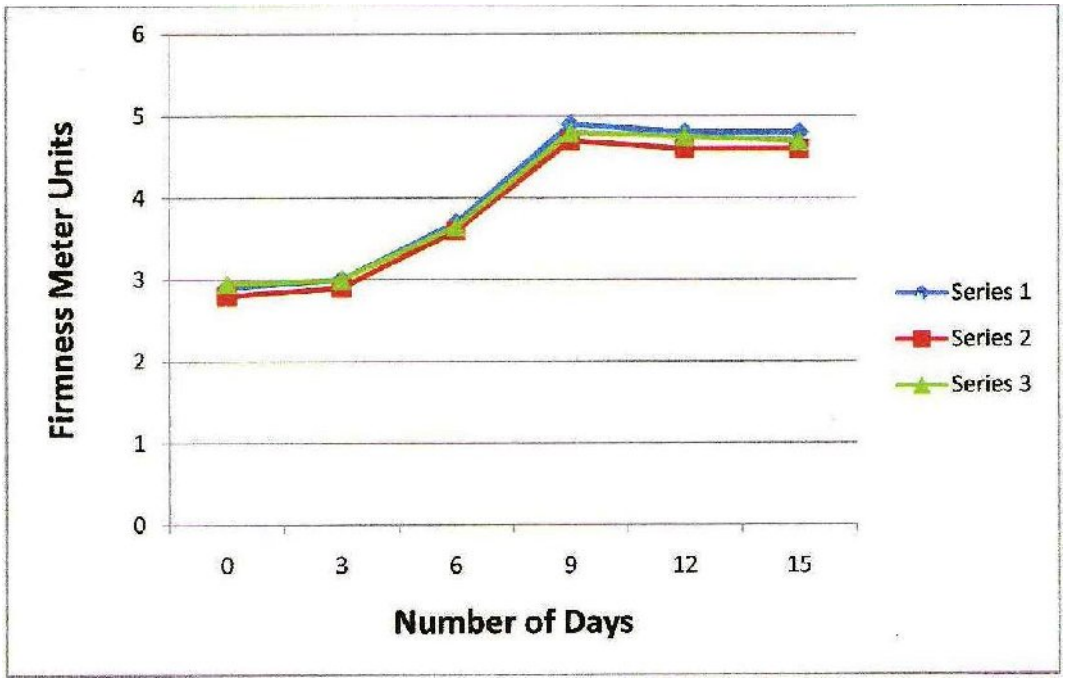


Figure 7: Temperature variation with time (after charcoal wetting and fan was on)



Series 1 – pawpaw, Series 2 – tomato, Series 3 – banana

Figure 8: Charcoal cooler without solar technology



Series 1 – tomato, Series 2 – pawpaw, Series 3 – banana

Figure 9: Charcoal cooler with solar technology

Table 1: Starch tests on vegetables (Charcoal cooler without solar technology)

Storage time	*Spinach*	*Kales*
Fresh product	Blue-black colour	Blue-black colour
Week 1	Plain blue colour	Plain leaf with few blue traces
Week 2	Faint blue colour	Plain leaf/no trace of blue

Table 2 Starch tests on vegetables (Charcoal cooler with solar technology)

Storage time	*Spinach*	*Kales*
Fresh product	Blue-black colour	Blue-black colour
Week 1	Blue colour	Plain blue colour
Week 2	Faint blue colour	Faint blue colour

Table 3: Vitamin C tests on Fruits (Charcoal cooler without solar technology)

Storage time	*Paw paws*	*Carrots*	*Tomatoes*
Fresh product	5.87	6.29	6.75
Week 1	5.88	6.48	6.85
Week 2	5.96	6.78	6.97

Table 4: Vitamin C tests on Fruits (Charcoal cooler with solar technology)

Storage time	*Paw paws*	*Carrots*	*Tomatoes*
Fresh product	5.85	6.27	6.76
Week 1	5.86	6.36	6.82
Week 2	5.90	6.53	6.98

Table 5: Variation of product weight (Charcoal cooler without solar technology)

Product	*Fresh weight (g)*	*Weight after 14 days (g)*	*% water loss*
Spinach	2.69	2.39	11.00
Kales	2.75	2.54	7.50
Cabbage	1133.00	1131.87	0.10
Bananas	86.00	85.91	0.10
Tomatoes	80.00	79.95	0.06
Carrots	75.00	74.78	0.30
Pawpaws	224.00	223.78	0.10

Table 6: Variation of product weight (Charcoal cooler with solar technology

Product	*Fresh weight (g)*	*Weight after 14 days (g)*	*% water loss*
Spinach	2.72	2.61	4.00
Kales	2.78	2.68	3.58
Cabbage	1102.00	1101.56	0.04
Bananas	82.00	81.98	0.03
Tomatoes	78.70	78.67	0.04
Carrots	78.40	78.24	0.20
Paw paws	228.00	227.86	0.06

Table 7: Variation of product Turgidity and Colour (Charcoal cooler without solar technology)

Storage time	*Kales*	*Spinach*	*Cabbages*	*Paw paws*	*Bananas*	*Tomatoes*	*Carrots*
Fresh product	Green, turgid	Green turgid	Green outer leaves	Greenish yellow	Greenish yellow	Pale red, turgid.	Orange, turgid
Week1	Pale yellow, little shrunk	Black shade, wilted leaf	Outer leaves bleached along the edges.	Yellow, turgid appearance	Yellow appearance	Red coloured, turgid	Orange, traces of mould growth
Week2	Yellow, wilted / shrunk	Complete blackening,wilted leaf	Increased bleach on outer leaves	Yellow, softer, traces of mould on surface	Darker shade, shrunk.	Red, increased softness.	Orange, grey mould on surface.

Table 8: Variation of product Turgidity and Colour (Charcoal cooler with solar technology)

Storage Time	*Kales*	*Spinach*	*Cabbages*	*Paw paws*	*Bananas*	*Tomatoes*	*Carrots*
Fresh product	Green, turgid	Green, turgid	Green, turgid outer leaves	Greenish yellow	Greenish yellow	Pale red, turgid	Orange, turgid
Week 1	Green, leaf little shrunk	Green, wilted leaf.	Outer leaves green, little loss in turgidity	Yellow, turgid appearance	Yellow appearance	Red coloured, turgid	Orange, little loss in turgidity
Week 2	Yellowish green wilted /shrunk	Traces of black, wilted leaf	Outer leaves bleached along the edges	Yellow colour, increased softness	Darker shade, little shrunk	Red, increased softness	Orange, traces of grey mould on surface

4.0 Conclusion and Recommendations

The results of this research have shown that incorporation of solar energy in providing power to drive a fan in a charcoal cooler improves the storageability of perishable agricultural produce. Leafy vegetables such as spinach and kales can be stored in the solar-charcoal cooler for up to about 11-12 days as opposed to a period of only three days where the solar powered fan is not incorporated. Fruits on the other hand can be stored in the solar-charcoal cooler for up to two weeks without losing their desired qualities. This can be attributed to their smaller surface area to volume ratio. Most fruits also possess a waxy cuticle on their surfaces. It is important that they are properly handled to avoid inflicting injuries on to the surface of these products before and during storage. The use of solar energy should be encouraged since it is one of the green/renewable sources of energy. Applications of solar energy are possible in all regions which receive sunlight and will result in savings as a result of reduced costs of electricity from the main national grid.

References

Baker, A. J. (1985). Charcoal industry in the U.S.A. Proceedings, ICFRO Meeting; 1985; Pretoria, Republic of South Africa. Forest Products Laboratory, USDA Forest Service, One Gifford Pinchot Drive, Madison, WI 53705 – 2398. 15p.

Bakker-Arkema, F. W., Debaerdemaeker, J., Amirante, P., Ruiz-Altisent, M. and Studman, C. J. (1999). CIGR Handbook of Agricultural Engineering. Agricultural Processing Engineering. Published by the American Society of Agricultural Engineers, USA.

Fellows, P. (1997). Traditional Foods. Processing for Profit. Intermediate Technology Publication, London, UK.

Gusfafson, R. J., Moray, R. V., Christenen, C. M. and Mernuk R. K. (1978). Quality changes during low temperature drying. *Transaction of the American Society of Agricultural Engineers,* Vol. **12** pp 162-169.

Hankins, M. (1995). Solar Electricity Systems for Africa. Published by Commonwealth, Science Council, London – England.

Herregods, M. (1994). Profitable Quality: Cost and Profits Concerning Marketing a Product Preferred by the Consumer. In COST 94, the Postharvest Treatment of Fruits and Vegetables, Quality Criteria, 5th Workshop Proc., Slovenia, Luxembourg, P. 21-32.

ITDG (2005). Refrigeration for Developing Countries. Htt://www.itdg.org/docs/technical-information-service/refrigeration.

Kader, A. A. (1983). Postharvest Quality Maintenance of Fruits and Vegetables in Developing Countries. In Postharvest Physiology and Crop Production, New York, pp 455-470.

Lindley, J. A. and Whitaker, J. H. (1996). Agricultural Buildings and Structures. Agricultural Processing Engineering. American Society of Agricultural Engineers, USA.

Michael, W. B., O. G. Schimidt (1986). Solar Drying in Africa. Proceedings of a workshop held in Dakar Senegal, 21st to 24th July.

Nation News Paper (2001). Horticulture Players Fight New Law. Tuesday, September, Nairobi - Kenya.

Odogola, W. R. (1994). Postharvest Management and Storage of Legumes. AGROTEC, UNDP/OPS Regional Programme, RAF/92/R51. Harare, Zimbabwe.

Shitanda, D. (2001). Storage and Processing Potentials for Horticultural Produce in Kenya. Paper Presented at the Sustainable Horticulture Production in the Tropics Workshop. Jomo Kenyatta University of Agriculture and Technology, Juja – Kenya, 3rd to 6th October.

Shitanda, D. and Wanjala, N. V. (2003). Effect of Different Drying Methods on the Quality of Jute (*Corchorus Olitorius L)*. Proceeding of the 3rd Asian-Pacific Drying Conference. Asian Institute of Technology – Bangkok, Thailand. 1st to 3rd September. PP 627 - 636.

Thompson, A. K. (1966). Postharvest Technology of Fruits and Vegetables. Oxford, Backwell.

SUB-THEME IV
INFORMATION AND COMMUNICATION TECHNOLOGY

ICT PENETRATION AND UTILIZATION IN LOCAL AUTHORITIES IN KENYA: THE STATUS AND IMPLICATIONS

B. M. Kiula[1] and J. M. Wafula[2]
Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya

Abstract
Effective penetration and utilisation of ICT in the public service for high-end value-adding operations in local government is crucial to enhance effective and efficient services that satisfy the citizens and other stakeholders. ICT penetration and utilization in the local government has not reached the levels necessary to reap the benefits of ICT in service delivery. This study sought to find out the status of ICT penetration and utilization and what the observed status implies. Three councils were purposively selected for this study. Stratified random sampling was employed to obtain respondents within the councils. Eighty respondents were obtained with a ratio of proportional allocation being used to allocate proportionate samples to the councils and their departments based on the respective staff populations. An ICT penetration and utilization index was developed based on a custom-made weighting. Pearson Moment of Correlation Coefficient and test of statistical significance were used to compare the strength of linear relationship between the index and ICT resources with descriptive statistics being used to analyze the results. ICT penetration and utilization was found to have a significant linear relationship with ICT resources, the level of education, age, length of service and the job scale of staff. Great investment in ICT resources and better educated staff was recommended towards improved ICT penetration and utilization in local authorities.

Key words: ICT-penetration, ICT-utilisation, ICT-infrastructure

1.0 Introduction and Literature Review

As a result of the limited resources allocated to most of the local authorities (2006 Kenya ICT Strategy) and their inability to generate sufficient revenue flows, most perform at the minimum even though the responsibility vested upon them in terms of public service delivery is enormous. It is noted that ICT infrastructure is essential to develop and implement e-government projects (Reilly *et al.,* 2003) of which local authorities form an indispensible part.

The Kenya Vision 2030 considers infrastructure development as a key enabler of economic, social and political development of the nation (GOK, 2007) while admitting that the country lacks adequate ICT infrastructure (GOK, 2006). The country therefore set out to develop a robust infrastructure. This momentum in infrastructural development includes power, road, rail, air and water transport, Internet backbone across all towns and telecommunications installations among others. The availability of ICT infrastructure is key to accelerated run towards the achievement of an information society status (ITU-WTD, 2003).

It is noted that any additional dollar invested into the purchases of ICT capital per individual in Latin America, developing Asian or African countries increases efficiency (and consequently service delivery) by almost ten times (Repkine, 2008).

This picture is replicated in the developed countries with every one dollar of broadband investment in the US yielding up to ten times while faster deployment of broadband in Europe is expected to create over one million jobs in Europe by 2015 (WEF, 2009). Thus, improving ICT infrastructure in Kenya would be expected to improve economic development and service delivery tremendously.

ICT plays a critical role in the success of e-government projects. It is argued that Arab countries must take actions to increase the penetration of e-government projects to reach the objectives of the Arab world (Ibraheem, 2008).

However, the acquisition of information systems, including computers and related hardware and software systems may not offer sufficient service delivery results. People are as important as technology and listening to workers' views about how ICT could improve the quality of public services delivery would help public services use of ICT more efficiently and effectively (Alexandra & Laura, 2005). It is thus critical that workers are involved in making decisions in the process of acquiring ICT infrastructure; be it software, hardware or human resources.

It is noteworthy that prior to the Kenya E-Government Strategy most local authorities outsourced computer generated accounts, budgets and reports and as of 2004 there were plans to acquire own personnel and computer systems (Wafula and Wanjohi, 2004).

The KLGRP was thus formed with the aim of improving local authorities' financial management and revenue mobilization by spearheading the development of an Integrated Financial Management System (IFMS).

2.0 Methodology

2.1 Sample and Sampling Design

Three councils were purposively selected for the study out of the 175 councils in Kenya. A sample of eighty respondents was drawn for the entire study. To ensure a fair representation for the three councils and the respective departments proportional allocation was used (Kothari, 2004) as shown below.

Ratio of proportional allocation used: $n_i = n\,{}^{y}\!/_{x}$ Where n_i is the strata sample size, n is the overall sample size, y is the strata size and x is the total population. Stratified random sampling was used for the study given the heterogeneity of the target population (Kothari, 2004). Samples were drawn randomly from the respective departments in each of the three councils.

Using this ratio the eighty respondents were allocated to the councils as shown in Table 1 below.

Table 1: Sample Size by Council

Council	Total Population	Sample Size
Municipal Council of Thika	503	50
County Council of Thika	187	19
Municipal Council of Murang'a	113	11
Total	**803**	**80**

Similarly, the respective departments within each council were allocated a number of respondents the same ratio of proportional allocation.

2.2 Data Collection Instruments and Data Collection

2.2.1 Data Collection Instruments

Primary data was collected as per the sample design. Two instruments were used as follows:

Structured Questionnaire

The researcher used a structured questionnaire which was researcher-administered (administered face to face with the respondent) to cushion the inability of the respondents to easily interpret some specialized questions (Mugenda and Mugenda, 2003). The questionnaires consisted of mainly closed and a few open-ended questions.

Interviews for Specific ICT Resources

Interviews were used to obtain information on specific ICT resources including bandwidth, number of computers and printers and ICT budgetary allocations to complement the questionnaires in the research. The interviews were conducted during the same time period with the administration of the questionnaires.

2.2.2 Data Collection

The questionnaires were administered within each department (stratum) in the respective councils based on simple random sampling of respondents as per the sample and sampling design. These questionnaires were administered directly by the researcher to ensure clarity of technical ICT terms to the respondents and maximum return of the questionnaires. The overall response rate for the three councils was 75 questionnaires against an expectation of 80, representing an overall response rate of 93.75%.

3.0 Data Analysis

3.1 Weighting of ICT Penetration and Utilization Indicators

OECD provides guidelines on organizational ICT indicators and comparable statistics on access and use of ICT but it does not give recommendations on the use of a particular type of sample frame, sampling methodology, processing of collected information, imputation and weighting of data (Robert, 2005).

However, weighting is important noting that the various elements of ICT do not have equal contributions to ICT penetration and utilisation (such as the high prevalence of telephone extensions which would give a false high level of ICT penetration).

For the purpose of this study an ICT penetration and utilization index was developed based on the perceived contribution by each element to ICT penetration and utilization.

Access weights of range 1 to 10 were allocated to the elements as shown in Table 11 below.

Table 2: Access weighting

Element	*Weight Allocated*
Direct Telephone Line	2
Telephone Extension	1
Computer	10
Mobile Phone	4
Personal E-Mail Address	3
Institutional E-Mail Address	10

Under this weighting the possession and use of an institutional e-mail address (@mct.go.ke, @mcm.go.ke or @cct.go.ke) carries greater weight than personal e-mail address (@yahoo.com, @hotmail.com…) because the presence of an institutional e-mail has an implied message that the institution has a mail server, website, local area network and, perhaps, ICT staff to maintain these facilities.

Usage weights were allocated on a scale of 1 to 5 based on the perceived level of sophistication of the user on the given ICT tool and the level of investment (skill effort and finance) to reach that level of usage as shown in Table 3.

Table 3: Usage weights

Use	Telephone	Computer	Mobile
Calls	1	5	1
E-Mail	3	4	2
Internet	3	4	2
SMS	4	5	1
Word Processing	2	3	5
Data Processing	2	3	5

The usage of mobile phones for word and data processing is considered a higher level of usage sophistication than the use on calls and SMS. Similarly, the use of the computer for calls and SMS represents a usage which finds the deeper value of computer utilization than the traditional aspects of word and data processing.

Using the weights earlier allocated, an ICT penetration and utilization index is developed using the formula shown below:

$$\bar{x}_i = \frac{\sum w_i x_i}{\sum w_i} * 100$$

Formula for the computation of weighted ict penetration and utilization index
Where w_i is the weight allocated to item i, x_i is the value of item i, while Σw_i is the sum of weights.

3.2 Correlation

The ICT penetration and utilization index obtained was correlated with the independent variables outlined in the literature review to reveal the strength of linear relationships using the Pearson Moment Correlation Coefficient (McClave & Dietrich, 1994) value, r, and statistical significance value, p, with the assumption of linear relationship between the independent and dependent variables and the presence of a large number of independent causes operating in both variables to cause normal distribution (Kothari, 2004).

Positive values of r, with r ranging between -1 and +1, indicate positive linear relationship between the variables under consideration while negative values indicate negative linear relationship. Values close to or equal to 0 are construed to mean weak linear relationship while values close -1 or +1 were construed to mean strong linear relationship. A test of statistical significance value, p, is used with the level of significance set at 5%.

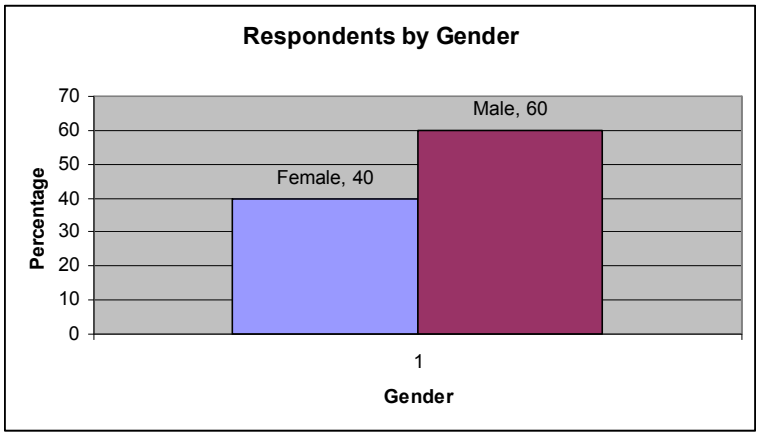
Therefore, correlations with p values below 0.05 and r values close to ±1 are accepted as denoting a significant linear relationship.

4.0 Findings and Discussion

4.1 General

4.1.1 Gender Representation

The findings indicate that the councils have a fair gender representation in employment with male and female employees representing 60 and 40 percent respectively as per Figure 2.



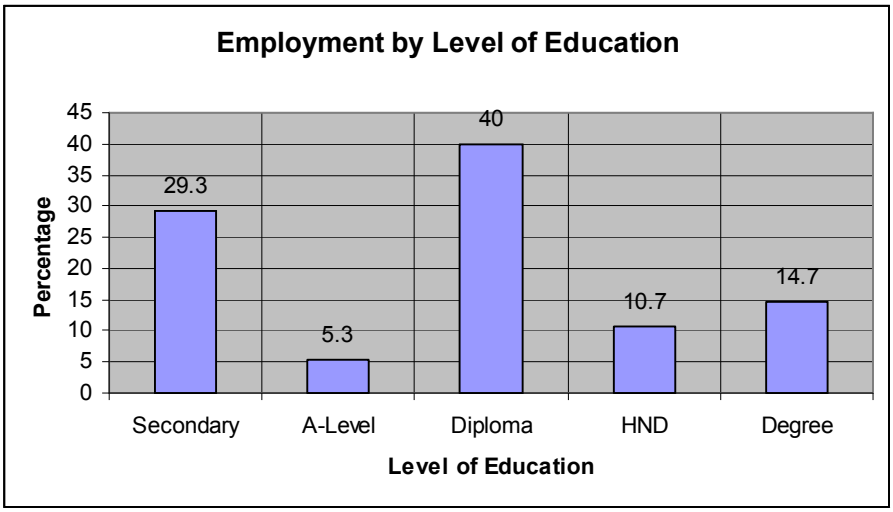
n = 75

Figure 16: Gender representation in the survey

This corresponds well with the commitment to mainstream gender and the effort to make fundamental changes in opportunity and empowerment as well as the attainment of at least 30 percent representation in recruitment, promotion and appointment of women towards the Kenya Vision 2030 (GOK, 2007).

4.1.2 Education

A simple majority of employees in the councils have diploma as the highest level of education followed by secondary school education with degree and higher national diploma a distant third and fourth in that order as shown in Figure 3.



n = 75

Figure 17: Level of education of respondents

This status with respect to the level of education implies that while the local authorities are charged with key public services most of the staff lack advanced education with 29.3% being secondary school leavers and over 70% having a diploma or below. Degree holders account for a meager 14.7% of the staff.

4.2 Level of ICT Penetration and Utilization

Using the data obtained in the survey in percentages the level of ICT penetration and utilization obtained was a mean of 43.58% with a standard deviation of 14.96%. However, for the purpose of this study an ICT penetration and utilization index was computed based on custom-made weighting as explained in Section 3.8.1. The analysis herein was based on the computed value of ICT penetration and utilization index.

The councils in the survey recorded mean ICT penetration and utilization levels of 30.12%, 33.13% and 28.66% for MCT, MCM and CCT respectively while the overall mean ICT penetration and utilization for the three councils was 30.15% as shown in Table 4.

Table 4: Overall ICT Penetration and utilization in the survey

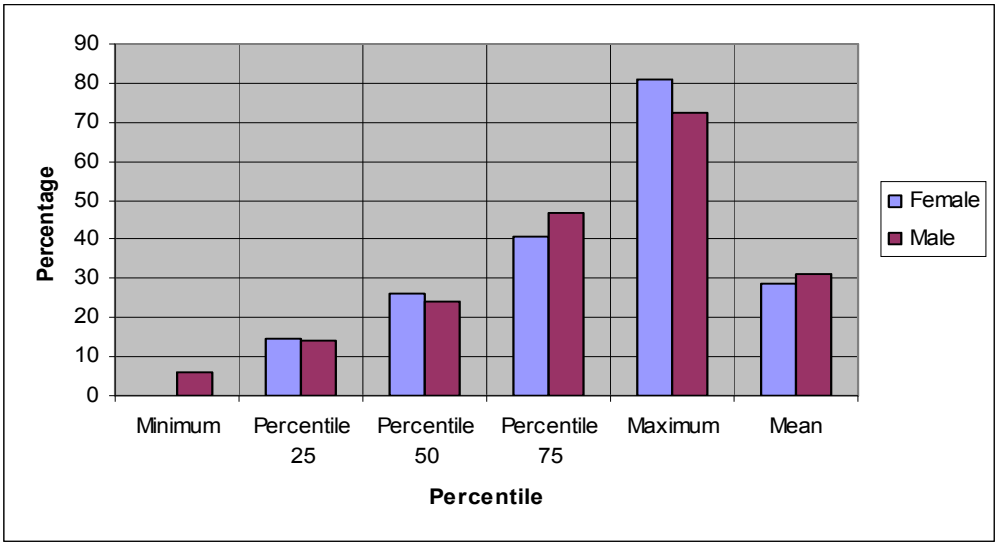
Council	Min.	Percentile 25	Percentile 50	Percentile 75	Max.	Mean	Std Dev.
MCT	6.02	14.46	11.44	18.08	80.72	30.12	17.74
MCM	8.43	11.75	25.6	13.55	61.45	33.13	18.8
CCT	0	10.84	12.05	20.48	72.29	28.66	20.53
Overall	0	14.46	10.84	18.07	80.72	30.15	18.4

n = 75

Table 4 above shows the level of ICT penetration and utilization along the percentiles for the three councils surveyed and the overall level for three councils combined. The uppermost row indicates the level attained at each percentile while the leftmost column indicates the three councils and the overall penetration and utilization level. In the first percentile (1-25%) we have 14.46% level of overall ICT penetration and utilization. In the second (26-50%) and third (51-75%) percentiles we have 10.84% and18.07% respectively.

Considering the cumulative (sum of current percentile and the previous percentiles) figures across the percentiles, the overall ICT penetration and utilization the indication is that 25% of the respondents are at 14.46% level of ICT penetration and utilization, 50% respondents at 25.3%, and 75% respondents at 43.37%. Assuming that there were no errors in the sampling and sample design then the level of ICT penetration and utilization is quite low in all the councils involved.

There is no indication that the level of ICT penetration and utilization varies with gender. Both male and female staff was found to be at par across the percentiles with respect to the ICT penetration and utilization index as indicated in Figure 4.

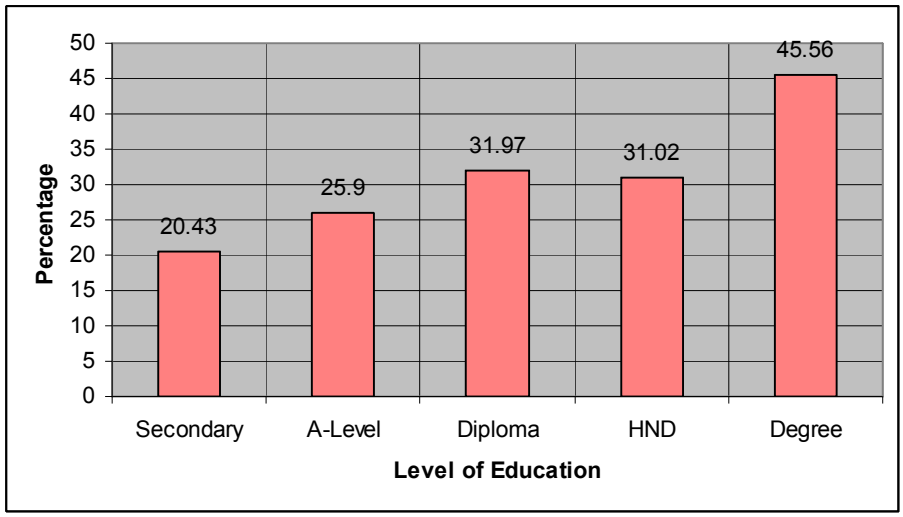


n = 75

Figure 18: ICT Penetration and utilization by gender

The level of education, on the other hand, has a strong linear relationship with ICT penetration and utilization. The ICT penetration and utilization is seen to gradually increase with an increase on the level of education from secondary school leavers at 20.43% to degree holders at 45.56% as indicated in Figure 5.

An investment in more educated staff is thus pertinent to improved ICT penetration and utilization.



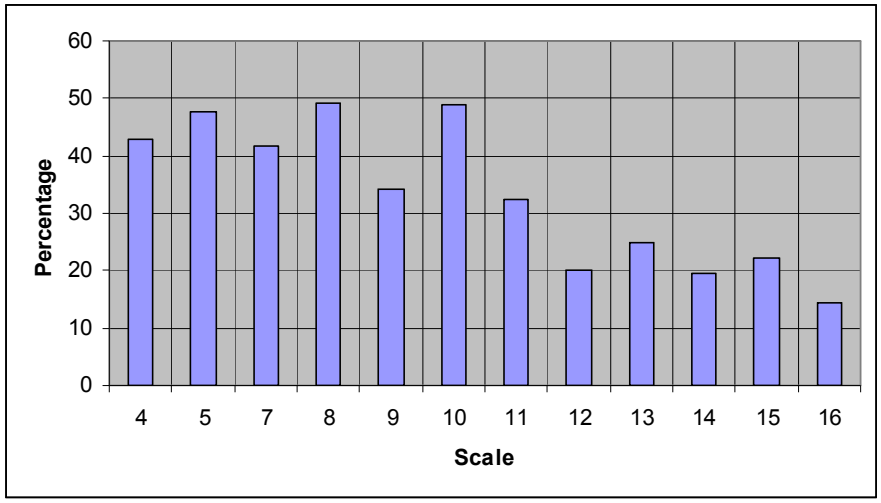
n = 75

Figure 19: ICT penetration by level of education

The above is further confirmed by the Pearson Moment of Correlation Coefficient value, r, of 0.416 and $p < 0.01$ meaning that there is a significant linear correlation between the level of education and the ICT penetration and utilization. This means that a greater investment in better educated staff would be an incentive towards an increased ICT penetration and utilization.

In addition, the Pearson Moment of Correlation Coefficient value, r, is -0.528 and $p < 0.01$ meaning that there is also a significant linear relationship between the ICT penetration and utilization and the job scale. As we go up the ranks the ICT penetration and utilization increases. In the local authorities the job scale or grades start with 1 the senior-most and end with 20 the lowest hence the negative value of r.

In the data obtained, the senior-most respondent was at scale 4. It is noteworthy that the ICT penetration and utilization index was significantly higher in job scale 4 to 10 than in job scale 11 to 16 as shown in Figure 6.



n = 75

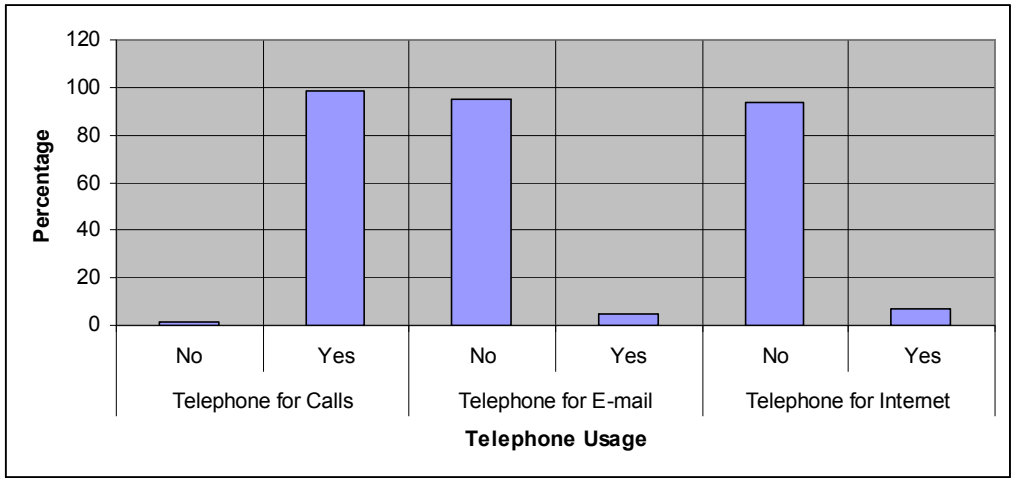
Figure 20: ICT penetration and utilization by job scale

4.3 Sophistication of usage of ICT Tools

Technology has evolved over the time especially in the era of convergence leading to the development of "intelligent multi-functional machines … capable of performing a whole range of ancillary tasks" (Cleary, 1998, p. 3). The telephone line as was in the history of telecommunications can now serve as a data line with a modem and thus be used to access e-mail and Internet. Similarly, the basic modern computer can support video conferencing with a web-camera, television, radio and telephone among others.

The mobile phone too has evolved in modern times to support banking services, radio and television, data processing and storage, camera as well as support telecommuting through remote access to institutional servers (Ndukwe, 2005). However, it is noteworthy that in this study the use of telephone, computer and the mobile phone is confined to the traditional functions and purposes only.

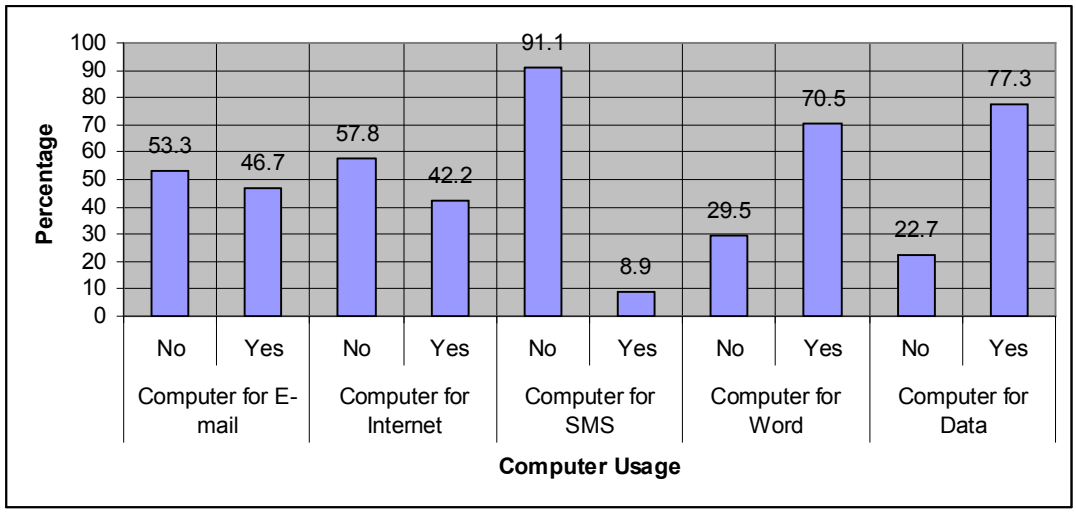
Figure 7 indicates that an overwhelming majority use the telephone only for calls.



N= 67

Figure 21: Diversity of telephone utilization

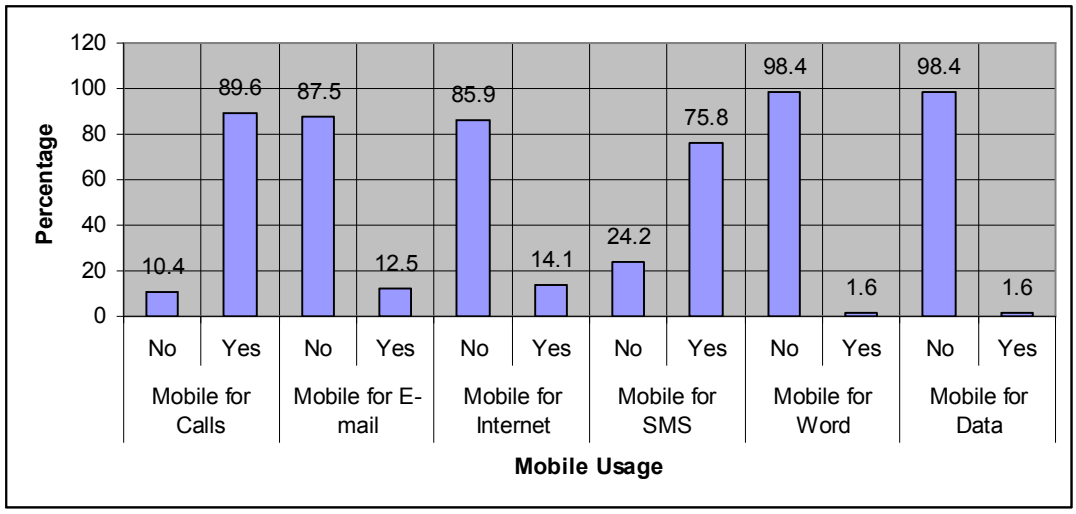
This situation is also replicated in the use of the computer for word and data processing as indicated in Figure 8. Given the rise of portals offering SMS services on the Internet it is quite surprising that the use of the computer for SMS is only an insignificant 8.9%. The percentage of staff utilizing computers for e-mail and Internet and those not using computers for the same is near equal.



n = 60

Figure 22: Diversity of computer utilization

It is clearly noticeable that the mobile phone is basically used only for calls and SMS from the Figure 9 below with an insignificant 12.5% and 14.1% using it for e-mail and internet respectively. The low use of mobile phone for advanced purposes may change as more capable mobile handsets set into the Kenyan market and costs go down.



n = 71

Figure 23: Diversity of mobile phone utilization

It is thus clear that the utilization of telephone, computer and the mobile phone is highly confined to the traditional uses and therefore the benefits of convergence are yet to be reaped in the councils.

4.4 ICT Resources

The local authorities have managed to acquire the basic ICT equipment, allocate funds for ICT utilities and some ICT human resource. In all the three councils the ICT services are not a distinct department but are integrated in the treasury departments.

MCT in the 2008/2009 financial year, for instance, allocated KSh. 1,000,000 for computer and office equipment, KSh. 800,000 for postage and communication (including telephone, internet and

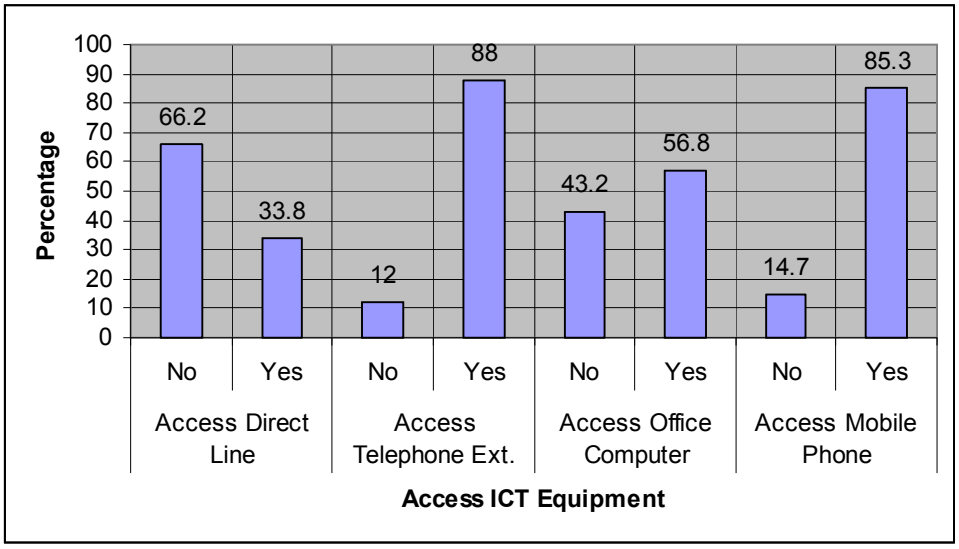
postage), KSh. 240,000 for ICT staff skills development and KSh. 1,500,000 for ICT staff salaries and emoluments. In addition, MCT has 40 computers and 21 printers with Internet bandwidth of 256 Kbps. MCT has 7 ICT staff that provides user support, implementation and maintenance services.

CCT, on the other hand, has 20 computers, 1 server and 7 shared printers. It also has a bandwidth of 256 Kbps. It has an ICT staff budget of KSh. 452,000 for the 2008/2009 financial year. In the 2007/2008 financial year it had a budget of KSh. 1,800,000 for ICT equipment. CCT has a specialist systems administrator under the job title of computer programmer and one computer operator.

MCM also has 12 computers and 5 printers. It had an allocation of KSh. 2,000,000 for the 2008/2009 financial year although not broken down to specific ICT elements. MCM does not have specialist ICT staff while access to the Internet is restricted to the top management based on a portable wireless broadband modem.

Correlating the ICT resources and its level of its ICT penetration and utilization it is noted that there is a strong linear relationship between the two. Using the Pearson Moment of Correlation Coefficient value, r, is 0.667 with $p<0.01$. There is a significant linear relationship between ICT penetration and utilization and ICT resources. ICT penetration and utilization index increases with increased investment in ICT resources in the councils.

Looking at the percentages of staff that have access to basic ICT equipment it is clear that access to a mobile telephone and telephone extension is exceptionally high as shown in Figure 10 below:



n = 75

Figure 24: Level of access to ICT equipment at the work place

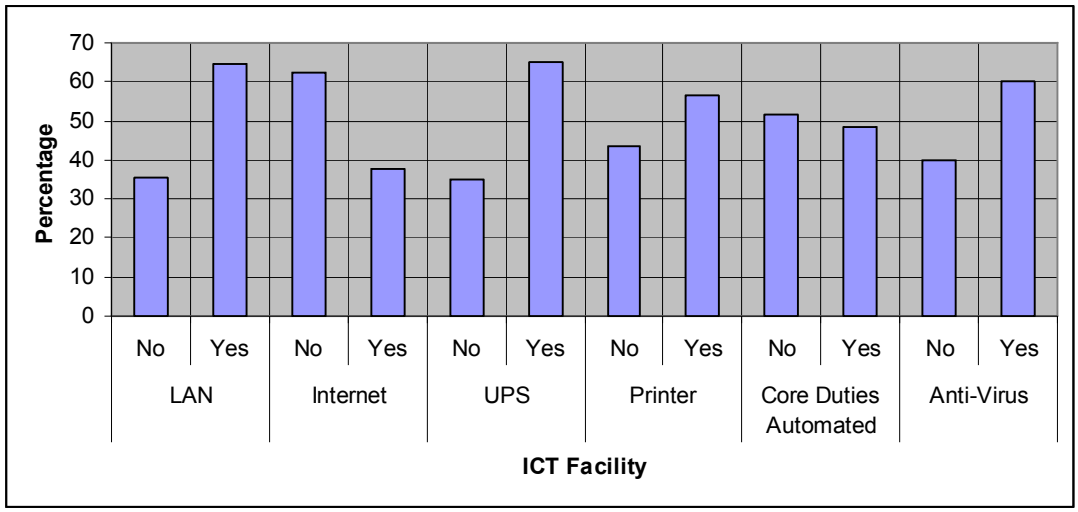
It is noteworthy that MCT has 40 computers and 21 printers against a staff population of 503 employees; CCT has 20 printers and 7 printers against a staff population of 187 employees while MCM has 12 computers and 5 printers against a staff population of 113 employees. This translates to 7.95 computers per 100 employees in MCT, 10.7 computers per 100 employees in CCT and 10.62 computers per 100 employees in MCM.

Clearly, sharing the meager computer resource against the high number of employees is a gargantuan task to achieve a 56.8% computer access rate for the people surveyed. However, the understanding of how these employees share the little computer resources at their disposal and the

level of effectiveness achieved under the circumstances is beyond the scope of this study and may be subject to further research.

It is also important to note that the Pearson Moment of Correlation Coefficient value, r, between the ICT penetration and utilization index and the number of supervised staff with computers is 0.471 with $p < 0.01$ indicating a significant linear relationship. This means that as the number of people with computers being supervised by an officer increases the ICT penetration and utilization also increases (see Roberts, 2005). This confirms the fact that more ICT resources consequently mean more ICT penetration and utilization.

A close look at Figure 21 overleaf reveals an important aspect. It is noteworthy that a simple majority of council employees have access to a local area network (64.7%), uninterrupted power supply system (65.2%), printer (56.5%), and anti-virus protection (60%). However, similar simple majorities have no access to the Internet (62.3%) and automated value-adding systems (51.4%) for their core duties (see Khamula, 2004).



n = 69

Figure 25: Strategic ICT facilities

The investment in the local area networks, computers, printers, reliable power systems and anti-virus protection may not be able to leverage the local authorities public service delivery advantage if access to information, e-government services and e-business is not availed over the Internet while on the other hand the core duties cannot be performed on the systems because they are not automated. It is thus important that, as noted earlier, the local authorities align ICT with their strategic plans to maximize on the investment in ICT.

5.0 Summary of Factors Affecting ICT Penetration and Utilization

Generally, the state of ICT resources was noted to exert the greatest influence on the level of ICT penetration and utilization. As the number of staff with access to a computer in a section increased the level of ICT penetration and utilization increased. Greater investments in ICT resources would thus be expected to improve the level of ICT penetration and utilization.

The level of ICT penetration and utilization was found to have a significant linear correlation with the awareness, attitude and skill of the staff. It also emerged that as the level of education improved and the job scale ranking increased to seniority the penetration and utilization index improved. In addition, it was noted that the ICT trainings for staff significantly improved their awareness, attitude and skill.

It was noted that the there was no significant linear correlation between the institutions management and its level of ICT penetration and utilization. It was, however, clear that the LAIFOMS information management system in the councils was driven by a strong championship of the government under the KLGRP and the will to ensure that the system was implemented successfully. LAIFOMS have consequently managed to streamline financial, operational and revenue management processes in the councils.

There was no significant linear relationship between the ICT penetration and utilization and the ICT policy, regulatory and strategy. However, a significant majority of 83.4% of the respondents indicated that they agreed/strongly agreed that an ICT policy needed to be part of the strategic plan of the organization underpinning the importance of embedding ICT in the core business of the councils. The role of government was highlighted with the performance contracting policies being considered a key influence to the penetration and utilization of ICT in the councils meaning that when the government reinforced the need to deliver effective services, the respective councils would consequently embed all technology tools possible to improve the operations. The government was identified by a simple majority as being a driving force towards the use of ICT in the councils.

The job scale, the level of education, the length of time in public service and the age of the council staff were also found to have a significant linear relationship with ICT penetration and utilization. The job scale, length of service and age of council staff had negative values for the Pearson Moment Correlation Coefficient because as they increase the ICT penetration and utilization decreased.

REFERENCES

2006 Kenya ICT Strategy, Ministry of Information and Communication, GOK, Nairobi, Kenya.

Alexandra, J. and Laura, W. (2005). How ICT? The Role of ICT in Public Services, viewed December 18, 2008 http://www.theworkfoundation.com.

Cleary, T. (1998). Business Information Technology, Financial Times: Prentice Hall, London, U.

GOK, (2006). Information and Communications Technology Sector Policy Guidelines, Government Press, Nairobi, Kenya.

GOK, (2007). Kenya Vision 2030: A Globally Competitive and Prosperous Kenya, Government of Kenya, Nairobi, Kenya.

Ibraheem, A. F. (2008), *ICT Penetration in Arab World and Its Effect on e-Government Projects* viewed December 17, 2008 http://publications/ksu/edu.sa/conferences/egovernment%2conference/e15.pdf

ITU-WTD, (2003). World Summit on the Information Society, World Telecommunications Development Report, ITU, Geneva, Switzerland.

Khamula, E. H. (2004). Global Indicators Workshop on Community Access to ICTs, ITU, Mexico City, Mexico.

Kothari, C. R. (2004). Research Methodology, Methods and Techniques, 2nd Edn, New Age International (P) Ltd Publishers, New Delhi, India.

McClave, J. T. and Dietrich F. H. (1994). Statistics, 6th Edition, Macmillan College Publishing Co., New York, USA.

Mugenda, O. M. and Mugenda, A. G. (2003). Research Methods: Quantitative and Qualitative Approach, Acts Press, Nairobi, Kenya.

Ndukwe, E. C. A. (2005). The Challenge of Creating Policy and Regulation in a Converged ICT Era, *Telecom World Africa Conference 2005*, Capetown, South Africa.

Reilly, C., Horan, J., Johnston, R., Stanley-Smith, C., Vincent, D. and Butler, C. (2003). eGovernment, More than an Automation of Government Services, Information Society Commission, Dublin, Ireland.

Repkine, A. (2008). ICT Penetration and Aggregate Production Efficiency: Empirical Evidence for a Cross-Section of Fifty Countries, MPRA Paper No. 7902, Muenchen, Germany.

Robert, S. (2005). Core ICT Indicators: Partnership on Measuring ICT for Development, UNESCWA, Geneva, Switzerland.

Wafula, J. M. and Wanjohi, N. G. (2004). ICT Policy and ICT Initiatives: What Linkages, Science for Humanity, IDRC, Ottawa, Canada

WEF, 2009, ICT for Economic Growth: A Dynamic Ecosystem Driving the Global Recovery, (2009) World Economic Forum Annual Meeting Report, Davos, Switzerland.

AUTONOMOUS INTELLIGENT COMPUTER BASED TRAINING – ROBOTICS

C. Wamuti, E. Mochoge, W. Mwangi
Institute of Computer Science and Information Technology, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: charleswamuti@yahoo.com

Abstract
This paper seeks shows how to extend Computer Based training - C.B.T by building independent components with intelligence. It explains the methodologies that could be employed given the new programming frameworks. Historically, CBTs growth has been hampered by enormous resources required: human resources to create a CBT program, and hardware resources needed to run it. However, the increases in PC computing power and especially the growing prevalence of computers equipped with CD-ROMs is making CBTs a viable option for corporations and individuals alike. Many PC application come with a modest form of CBT, often called a tutorial (Webopedia, 2009). A common example of a CBT is Microsoft's Encarta. Despite this goodness of a CBT, they suffer a really big problem, that is, they are only accessible on a mainframe, not from a remote site. This makes such systems not offer the goodness foretold by e-learning systems. But then, there must be a solution for this. The answer is yes. The answer is: "... several distinct physical components working together as a single system," (Barnaby, 2002). Following Barnaby's approach, it is natural to think about a central controlled system managing intelligent agent that teaches in class rooms.

Key words: Artificial intelligence, agents, e-learning, robots, computer based training

1.0 Introduction

The main goal of training is to impart relevant information and knowledge to trainees in a cost effective and suitable manner. Relevant information should be up-to-date, from reliable sources and timely presented. A while back, education was only limited to four walls and a roof, that is, a class room. Professionalism was practiced to its acme; even courses geared on teaching teachers how to teach were incepted. The ultimate goal of such efforts was to make training more productive. However, the dynamics of the last quarter of the 20th Century did not allow confinement to a physical four-walled classroom in order to pass knowledge. Computer Based Training (C.B.T.) [1] came to the rescue. Initially C.B.T.s were implemented as standalone[2] applications. The 21st Century has seen the Internet prevail on every aspect of our lives including knowledge acquisition. This has seen C.B.T. programs being enhanced to allow the reception of updates to ensure up-to-the-minute information. A typical example is Microsoft's Encarta encyclopedia. However, we need a mechanism that exhibits some form of intelligence to facilitate timely search and retrieval of relevant information and knowledge in a cost effective and delegated manner from designated sources. How can we actualize this?

1.1 Agents

An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors (Russell and Norvig, 2002). A Web searching agent is a program that automatically traverses the Internet using the Web's hypertext structure. The agent can either retrieve a particular document or use some specified searching algorithm to recursively retrieve all Web documents that are referenced from some beginning base document (Jaasen *et al*., 2003) Just as humans search for items over the internet, so can the same be accomplished by the use of a web searching agent. These agents can be sent 'outside' there to obtain information and bring to where it is needed. A computer based training program can really be of great use if it can make use of this agent. The C.B.T. needs to exhibit some level of autonomy[3] through the agents. These agents are supposed to look for credible information from designated sources.

As a description of how the autonomous agents will work, there will be two types of cooperating agents. One will be a worker agent and the other will be a supervisor agent. This interaction is depicted in Figure 1 below:

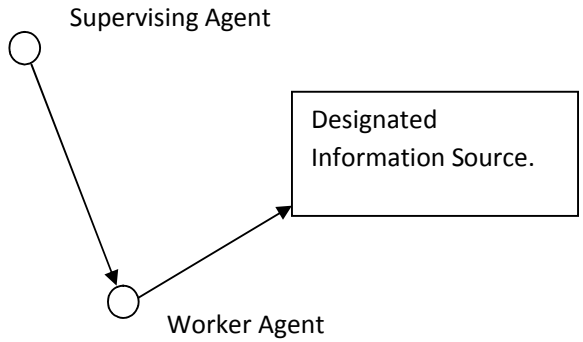


Figure 1: A Supervising agent observing a worker agent retrieving required information from a designated source that has been found

[1] Computer Based Training: it is a type of training in which the student learns by running special training programs on a computer.
[2] Standalone: Able to operate as a self-contained unit independently of a computer network or system.
[3] Autonomy: working independently of external intervention.

The supervising agent monitors the tasks carried out by the worker agent to ensure non-deviation from intended actions. Of course, it doesn't mean that a supervising agent can only be attached to one worker agent. Actually multiple workers can be supervised by one or more supervising agents as deemed appropriate. How does this work?

Suppose that in the training process the C.B.T. realizes a need for information and/or knowledge not currently held, it invokes agents to go for an information search, location, and retrieval mission. We propose that at the initial phase of information search, one or two agents can be sent to the field[4] together with one supervisor agent. Then the worker(s) is allocated a reasonable amount of time within which to find the target information. If it (worker agent) takes longer than anticipated, then more worker agents and associated supervisors are dispatched to aid in the target information location and retrieval. The major advantage in using multiple agents, similar to using multiple people in human teams, comes from the concept of synergy. Synergy is the concept that the behavior of a system as a whole is more than just the sum of its parts. By having multiple agents in a given environment operating in parallel there are obvious advantages as to the amount of work which must be done by each to complete a task or tasks at the global level (Randall Fletcher and Dan Corbett). Synergy means that the relationship which the parts have to each other is a part in and of itself (Covey S.). Covey asserts that it is not only a part, but the most catalytic, the most empowering, the most unifying, and the most exciting part.

This approach is precast around work (Sabu *et al.,* 2005), in their seminal paper titled "An Agent Based Peer-to-Peer Network with Thesaurus Based Searching, and Load Balancing" presented at the *International Conference on Computational Intelligence for Modeling, Control and Automation, and International Conference on Intelligent Agents, Web Technologies and Internet Commerce (CIMCA-IAWTIC)*. They propose a system that makes use of several types of cooperating agents that enables efficiency i.e. a master agent that manages and controls the collection of other agents referred to as search agents and resource watcher agents.

To eliminate chances by the newly dispatched agent group from visiting an already searched information repository, the supervisor(s) of the initially dispatched group will keep track of all the nodes traversed but bearing no fruits, and inform the supervisor(s) of the newly dispatched agent group. In turn, this supervisor(s) informs and ensures that its worker agents do not traverse these already visited nodes. This logic is depicted in the figure below.

[4] Field: The world wide web.

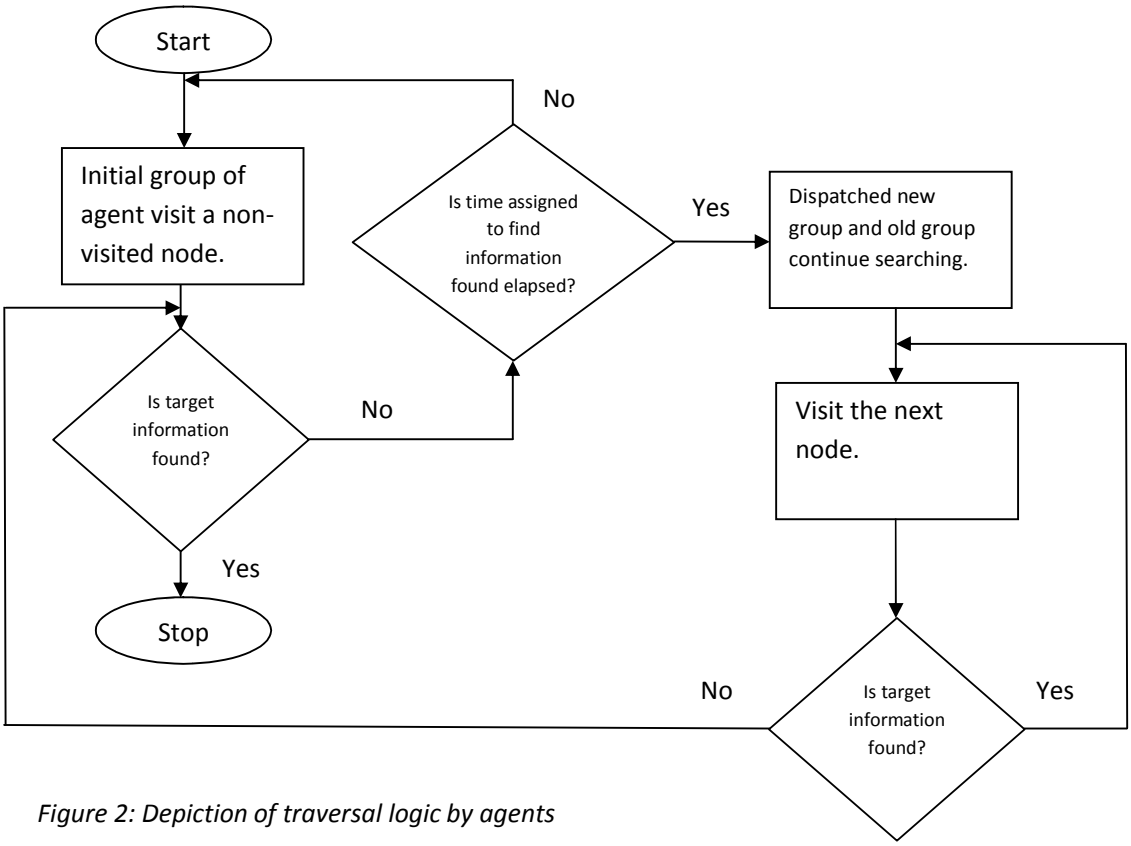


Figure 2: Depiction of traversal logic by agents

The goal of all this is to avail needed information and/or knowledge to the C.B.T. program in a timely fashion. But is such kind of interaction, traversal and communication even possible?

1.2 A proposed Architecture

1.2.1 The Worker Agent

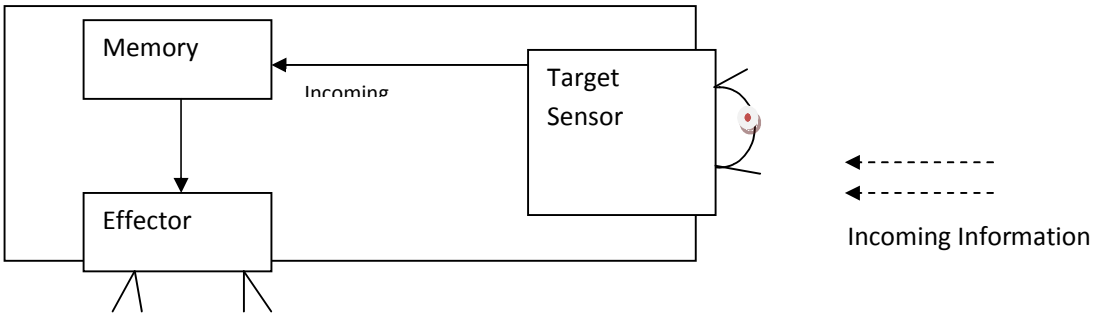


Figure 3: The worker agent architecture

1.2.2 Memory

Stores current state for example current position in the field, intended location, log (errors encountered and environmental threats).

1.2.3 Target sensor

Extracts and uploads the required information from the environment and stores in memory. Information includes target information for the C.B.T., security threats in the environment, and errors encountered. It also accepts instructions from the supervisor agent.

1.2.4 Effector

Interacts with the environment as well sends information held in memory to the supervisor agent. It is responsible for navigation through the field as guided by the supervisor through the target sensor.

1.2.5 The Supervisor Agent

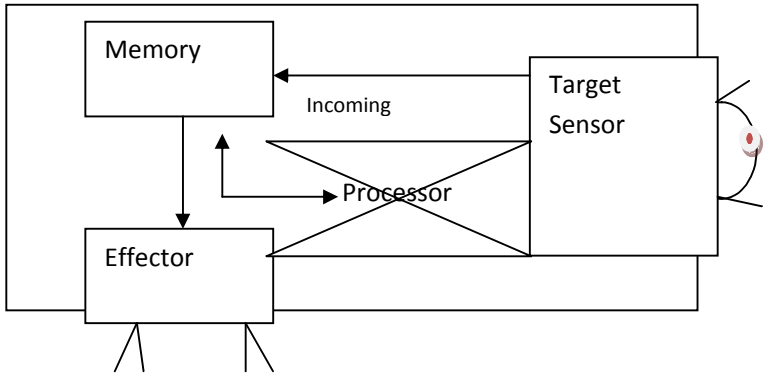


Figure 4: The supervisor agent architecture

2.0 Memory

Stores current state information, for example, the intended and current position of itself and the worker agents under its supervision in the field, worker agents' entire field-life time state. This information is valuable to the developers of agents for possible future improvement. Such improvements, we propose, could be like getting permissions from servers containing target information since, as of late, there have been serious efforts on enhancing server security. The memory also stores information regarding errors encountered by agents i.e. the supervisor and the

workers under its supervision, and any environmental threats encountered by both, for example, virus attacks or hackers[5] and sniffers[6].

2.1 Target sensor

This, just like the worker agent's target sensor, extracts and uploads required information from the environment and stores the same in memory. Information includes target information for the C.B.T., security threats in the environment, and errors encountered.

2.2 Effector

The supervisor agent interacts with the environment as well sends information held in memory to other agents through its effector. The effector is responsible for facilitating navigation through the field.

2.3 Processor

This is the part within the supervising agent that performs various operations such as logical deductions pertaining it and the worker agents. A typical example of when a processor comes in handy is when the supervisor has to decide on what to do in case the target site[7] is compromised by viruses, or the agents themselves are threatened by the viruses.

3.0 Conclusion and Recommendation

Computer Based Training programs play a vital role in the process of knowledge acquisition. The pervasiveness of the internet in the 21st century in almost every aspect of human life can be positively utilized for the enhancement of the quality and effectiveness of computer based training in the teaching-learning process. This paper proposes the use of autonomous agents that can aid in the process of information searching, location, retrieval and subsequent use by a computer based training program to meet training needs. Cooperation between the agents helps in reducing task completion time (in this case, information searching, retrieval and availing for use) and enhances the quality of information presented since information is gotten from a variety of sources.
The paper presents a theoretical and idealistic approach, which if implemented, would enhance the quality of training offered by computer based training programs to meet the knowledge needs of the modern world.

This C.B.T. can be implanted in a robot and the robot can be placed in front of a class room and would lecture like a real teacher. A student can even ask question and by use of these agents and additional existing technologies such as Natural Language Processing and Machine Learning, a robot can easily train using this embedded computer based training module. Companies, such as Lego, have come up with programmable robots like the Lego MindStorm NXT and these robots are quite inexpensive (available at *http://shop.lego.com/Product/?p=8527*). Morgan (2008) observes that:

> "Robotics is a field that has been around for several years. It has long been associated with artificial intelligence, but, for many people, robotics is seen as a practical solution in a world desperate for automation."

Thus, the use of autonomous agents in eLearning is revolutionary and fulfills the promise foretold. As a future direction, we plan to actualize these agents in real robots.

---

[5] Hacker: A computer user who gains unauthorized access to a computer system or data belonging to somebody else

[6] Sniffer: A program on a computer system designed legitimately or illegitimately to capture data being transmitted on a network, often used by hackers to appropriate passwords and user names.

[7] target site: This is a location, such as a server on the www, that holds information that the C.B.T. is interested in.

References

Russel, S., Norvig, P. (2002). Artificial Inteligence: A modern approach, 2nd Ed. Prentice Hall, New Jersey.

Jaasen, B., Spink, A., Pedersen, J. (2003). Web Searching Agents: What Are They Doing Out There? Proceedings of 2003 Australian-New Zealand Conference on Intelligent Information Systems. Adelaide, Australia, 20 November.

Fletcher, R., Corbett, D. (1996). A Framework for Search and Retrieval Tasks Using Specialised Cooperating Autonomous Agent. Proceedings of 1996 Australian-New Zealand Conference on Intelligent Information Systems. Adelaide, Australia, 18-20 November.

Covey, S. (1989). 7 habits of highly effective peopl. Franklin Covey Co, New York.

Sabu, M., Thampi, K. and Chandrasekaran (2005). An Agent Based Peer-to-Peer Network with Thesaurus Based Searching, and Load Balancing. Proceedings of the 2005 International Conference on Computational Intelligence for Modelling, Control and Automation, and International Conference on Intelligent Agents, Web Technologies and Internet Commerce (CIMCA-IAWTIC'05). Maui Hawaii, 23 August.

Morgan, S. (2008). Programming Microsoft Robotics Studio, Microsoft Press, Redmond Washington.

Barnaby, T. (2002). Distributed Net Programming using C #, Apress, Berkely California.

SECURITY ISSUES FACED BY MOBILE CASH TRANSFER APPLICATIONS IN KENYA ON GSM AND 3G NETWORKS

G. W. Chemwa
Institute of Computer Science and Information Technology, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: chemwex@icsit.jkuat.ac.ke

Abstract
This paper postulates that since mobile cash transfer and banking applications security architectures were developed in obscurity, they could easily be cracked when they lose their obscurity. The paper investigates the security loopholes present on 3G networks and their likely impact on the security of cash transfer and banking applications. The study also looks at the security of the applications themselves and how biometric authentication can be used to improve security through multimodal authentication.

Key words: Mobile banking, 3G, mobile applications, security, convergence, mobile cash transfer

1.0 Introduction

The remarkable growth in access to mobile telephony in developing markets has created the possibility of delivering new financial services by leveraging secure, low-cost mobile networks and platforms (Hughes, 2007). Kenya now has four mobile cash transfer services in the form of Safaricom's M-PESA, Zain's Zap, Yu's Yu Cash and Orange's Orange Money. These services have a subscriber base of over fifteen million (15M) and transact over four hundred billion Kenya shillings a year (CBK, 2009). Most of these systems are text based and access is controlled using a four digit password only. The introduction of mobile banking services like M-Kesho by Equity bank, KCBConnect by Kenya Commercial Bank (KCB) and Pesa Pap by Family Bank has introduced new security challenges at the various inter-network points of convergence, more specifically vulnerabilities in the Switching System 7 (SS7) protocol used for GSM networks. Already, a security firm in the United States of America discovered gaping security loopholes in mobile banking applications which could allow a person to acquire the user name, password and account details from iPhone and Android phone memories (Spencer, 2010). In a developing country like Kenya, the mobile user for the foreseeable future will find utility in standard (basic) handsets. Feature phones and Smartphone's are still a shilling too expensive. Standard handsets do not have facilities to secure or encrypt data before sending it to server based applications at the mobile financial services providers (mFSP) or the ability to run programs (Trust, 2008). This paper will analyze the security vulnerabilities of 3G networks, explore the security of applications architectures and conclude by looking at various biometric authentication vectors and how they can enhance mobile applications security.

2.0 Materials and Methods

This paper was compiled on the basis of: personal knowledge and experiences of the author; published reports from various sources listed in the references; interviews with staff in leading mobile cash transfer and banking providers; interviews with customer outlet agents for mobile cash transfer; interviews with users chosen at random in both urban and rural Kenya.

3.0 Results

The mobile handset consists of various stand alone or client applications whose general architecture is as depicted in Figure 1. The picture shows that security cuts across the application architecture.

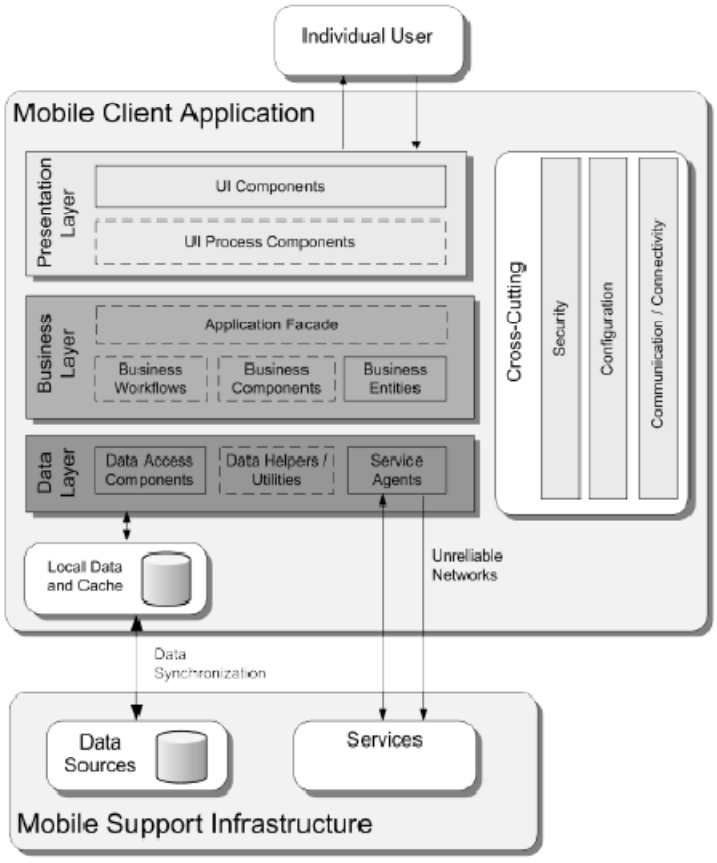


Figure 1: The mobile phone application architecture ©Microsoft Patterns & Practices 2008

All the Kenyan mobile network operators (MNO's) are struggling to move from second generation (2G) to third generation (3G) platforms. Safaricom was the first to launch the 3G platform while the other networks have moved from 2G to 2.5G and 2.75G. This paper therefore focuses on the security issues on 3G networks, since this framework tries to address loopholes that existed on earlier networks. Table 1.0 shows the evolution of mobile networks, technologies and applications.

Table 1: Evolution of mobile networks, technologies and applications

	Year	*Voice*	*Sms*	*Analog*	*Video*	*Digital*	*Gprs*	*Edge*	*Hspda & Wimax*	*Web*	*Basic . / Advanced. Multimedia*	*Apps*	*Speeds*
1G	1980 – 90s	•		•								None	low
2G	1990s	•	•			•				•		Thin clients, Voicemail, push-to-talk, conference call, caller ID, voicemail,email, web	20Kbps
2.5G	2000 To Date	•	•			•	•	•		•	•	Rich clients, Faxing, browsers, basic multi-media, mapping, light games	90Kbps
3G	Present	•	•		•	•	•	•	•	•	••	Video on demand, video-conferencing, VoiP, music, TV, satellite radio, stand alone Apps, advanced games	2+ Mbps
4G	Future	•	•		•	•	•	•	•	•	••	Complete rich apps	1 Gbps

Mobile cash transfer and banking applications in Kenya such as M-Pesa, Zap and Yu Cash are thin clients based on short message service (SMS) and unstructured supplementary service data (USSD) technologies. In order for an intruder to perform an attack, they must be able to eavesdrop, impersonate the user or network, assume the man-in-the-middle position or compromise authentication vectors (3G TR 33.900, 2000). Table 2 lists the various security vulnerabilities of 3G networks, and indicates those that are yet to find solutions.

Table 2: Various security vulnerabilities

Vulnerability	*Description*	*Solved?*
1.0 Denial of Service	Attacks included deregistration spoofing, location update spoofing Camping on false BS or BS/MS	Yes No
2.0 Identity Catching	Attacks include passive identity catching, active identity catching	Yes
3.0 Network Impersonation	Attacks include encryption suppression between target user and intruder or network Impersonation of network forcing use of compromised cipher key	Yes Yes
4.0 Eavesdropping	Eavesdrop on user by suppressing encryption btw. user & network Eavesdrop on user by suppressing encryption btw. user & intruder Eavesdrop on user by forcing use of compromised cipher key	Yes Yes Yes
5.0 User Impersonation	Through use of compromised authentication vector Through use of compromised authentication response Hijacking outgoing calls with encryption disabled Hijacking outgoing calls with encryption enabled Hijacking incoming calls with encryption disabled Hijacking incoming calls with encryption enabled	Yes Yes Partly Yes Partly Yes

The findings elucidated in Table 2 means that simple access authentication at the application's interface is not enough to guarantee the safety of mobile cash and banking applications. Security should be viewed in a multilayered and multimodal manner as a function of many features some of which include the following: the need to enforce security at every layers of the communication protocol stack; handset/SIM/Smartcard security; internetwork security; intra-network security; application platform security and human administration/agent security.

GSM Layer 1 is normally understood to mean the control software which controls the radio and baseband hardware-the physical layer. Layer 1 multiplex the physical access to the radio channel and provides a number of logical channels which can be used for signalling. Layer 2 is responsible for establishing a data link on these logical channels to allow reliable transmission of Layer 3 signalling messages. Layer 3 is subdivided into a number of separate tasks including the radio resources manager, the mobility manager, and the connection manager.

The modern mobile network puts a lot of emphasis on the mobile handset and SIM card as fortified centers of security. Key security issues here include: the need to closely monitor how stolen or malfunctioning cards are replaced; the importance of controlling what applications are installed on the smartcard to avoid K_i loss and the need for SIM misuse tracking system.

The danger of a mobile user losing a handset to a person who may know the access codes both to the SIM and mobile cash transfer and banking applications cannot be overstated. In most cases this could be a close friend or relative.

The biggest challenge here is at the points of convergence between mobile networks and internet protocol (IP) based networks. The signaling System no. 7 (SS7) which connects this mobile to IP networks deals with security issues such as authentication, location updates and call control. Research shows that messages can be altered, injected or deleted into the SS7 signaling without proper control. This provides challenges where mobile cash transfer applications merge with IP based financial systems run by banks in Kenya. The increasing sophistication of the modern cracker with modern computer based tools and access gateways found on the internet creates real challenges to the security on mobile financial applications. There needs to be continuous screening of incoming SS7 messages to avoid messages that can create a denial of service (DoS).

The unauthorized access to mobile network assets and interfaces such as the Home Location Register (HLR), Authentication Center (AuC) and the Mobile Switching Center (MS) presents a real vulnerability to mobile cash transfer and banking applications. This is because such an access would expose confidential information. Unauthorized access to HLR can easily lead to activation of subscribers who are invisible to the billing system or cause a denial of service attacks. At this point privileged man-machine (MM) commands can be used to illegally manipulate other HLR's on the network. Secondly, unauthorized access to the AuC will enable an attacker to clone subscribers on the network. Lastly, a successful attack on MSC would result in the loss of confidentiality of user data, unauthorized access to services or denial of service for large numbers of subscribers.

Mobile cash transfer and banking applications can either be complete handset applications, mobile web applications or text based as illustrated in Figure 2.0. Each set of applications provides unique security challenges.

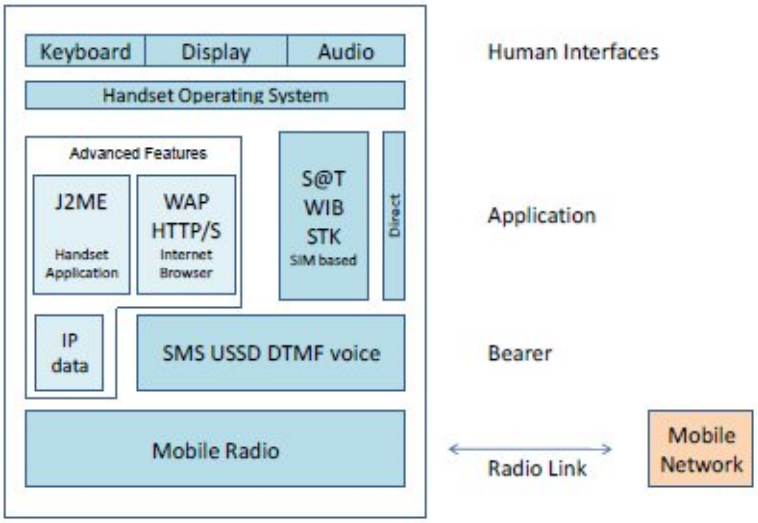


Figure 2: Mobile phone applications ©Bankable Frontier Associates 2008

SMS – Short Message Service USSD – Unstructured Supplementary Service Data J2ME-Java 2 Platform Micro Edition WAP- Wireless Application Protocol HTTP – Hypertext Transfer Protocol HTTPS – Secure HTTP IP – Internet Protocol

Table 3 summarizes the various technology platforms that mobile cash transfer and banking applications can be developed on and the risks associated with each:

Table 3: Technology platforms useful to mobile cash transfer and banking applications

Technology	*Application Scenario*	*Associated Risk*
SMS/USSD/MMS, Voice/IVR	Application runs on generic mobile bearer services	There is no encryption of information so the channel from the mobile to the mobile financial services provider is open to monitoring, replay, modification and impersonation
HTTP/S, WAP	Applications run on mobile browsers provided on the phone. They do not depend on mobile network providers.	These applications run on the mobile web and are accessible through mobile based browsers e.g. Opera Mini. The security of the applications depends on security standards such as secure socket layer (SSL) and browser security
J2ME, SYMBIAN, ANDROID	Applications use advanced services provided on the phone. These are rich clients connected to servers over mobile network. These applications are partly independent.	Mobiles less exposed to the Internet and the threats. SSL can be used. End-to-end security can be enforced.
SIM Toolkit, WIB, S@T and Java Cards	Applications use the secure environment provided by the mobile network operators.	This provides the highest end-to-end security. The application runs securely within the SIM and the encryption keys are kept within the SIM.

Weaknesses in the information security policy that governs access to network elements and information assets by employees, agents or external people can greatly compromise the security of the mobile applications and the supporting information communication and technology (ICT) assets. A granular approach to different user's access to mobile cash transfer and banking applications and other information assets must be implemented. On the other hand, all the paperwork needs to be properly classified to avoid sensitive documents falling into the hands of unintended staff. Physical access control to mobile information assets needs to be carefully thought out to deter both unauthorized insiders and outsiders from accessing them.

3.0 Discussion and Conclusion

The foregoing findings point to weaknesses in the mobile cash transfer and banking applications, mobile networks and administration issues which can impact on the security of cash transactions. The simple password access control on the application interface is not enough to assure security. Also, the vulnerability of the SS7 switching protocol at the points of convergence between mobile networks and IP based networks still leaves a lot to be desired. Although recorded attacks have been accidental, the future security terrain calls for urgent sealing of existing loopholes. Lastly but not

least, the false base stations attack has not been dealt conclusively even in 3G networks, and this can be exploited to cut genuine users off from their home network as the attacker tries to acquire confidential information from the user.

In view of these findings, it would be good to develop a multimodal security model especially at the points of user authentication in the applications and networks. Biometric technology comes in handy as a method that can be used together with other authentication vectors to enhance security of applications. Fingerprints and facial features authentication are two methods which are finding quick acceptance on mobile platforms. Facial identification needs to avoid replay attacks based on real life size photographs by analyzing the 3D images of video. The key challenge here is that the volume of code needed to achieve this feat may be too much for the mobile platform.

References

3GPP, (2000). A guide to 3rd generation security p.5-20. 3GPP Project, Antwerp.

Bankable Frontier Associates Trust F. (2008) *Managing the risk of mobile banking technologies p.3-33* Bankable Frontier Associates.

Chikomo, K. et al Security of mobile banking p.3-4 University of Cape Town, Rondebosch.

Guo, Y. and Chaskar, H. (2002) *Class-based quality of service over air interfaces in 4G mobile networks* P*. 132-137* IEEE Communication Magazine.

Gritzalis, S. et al Security protocols over open networks and distributed systems: Formal methods for their analysis, design and verification p. 1-5 University of Aegean, Athens.

GSI, (2008). Mobile commerce opportunities and challenges p. 43 Blue Tower, Brussels.

Kim, D. and Hong, K. (2008). Multimodal security authentication using teeth image and voice in mobile environment p.1-4 IEEE*,*NewYork.

Sarin, A. (2007). The transformational potential of m-transactions p.8-11 Vodafone, UK.

Sieger, H. (2010). User preferences for biometric authentication methods and graded security on mobile phones p. 1-2 Technische Universitãt, Berlin.

Zhu, B. et al (2009). PCM: A privacy-preserving detection mechanism in mobile ad-hoc networks p. 7 Wiley and Sons, USA.

OPEN SOURCE SOLUTIONS TO AUTOMATIC GENERATION OF TESTS AND EXAMINATIONS

J. M. Kihoro and R. Ibuka
E-learning Department, Jomo Kenyatta University of Agriculture & Technology, Nairobi, Kenya
Department of Statistics and Actuarial Sciences, Jomo Kenyatta University of Agriculture & Technology, Nairobi, Kenya
E-mail : kjm@fsc.jkuat.ac.ke

Abstract

One obvious challenge in any learning institution is testing and examining learners with standard papers. Many are the times that the examiners have little time to think through questions based on the provided course outlines especially if they have never taught the subject before. Availability of a database of past questions with expected answers can be very useful in orienting both the tutor and the students. This paper explains a system that provides an open source solution to dynamic generation of examinations through pre-set templates. The generation is achieved by integrating the capabilities of open source software to perform random selection of testing questions from a database of questions stored in a LaTeX file. The idea is to have a single file containing every approved question and accompanying answer and let the system randomly pick pre-specified number of questions on each request through a link. The selected questions are compiled into a Portable Document Format (PDF) output file, which can be printed or be saved for future administration. The system allows any type of question with excellent graphics when drawn using pstricks. The tutor can edit the existing template of questions by adding or deleting questions, modifying the answers and resetting the parameters such as the numbers of questions per exam. It is also possible to switch on and off the generation of the marking scheme. The system can be used by the exam processing office or just to support learning as a library support system. The main challenge is to convert all current and previous questions into latex as question-solutions format which must be as specified and thus the examiner requires initial training on use of Latex to typeset.

Key words: Random generation, latex, examinations, database

1. 0 Introduction

The core business of learning institutions is to train and examine their clients who are students. Colleges and Universities have to set many examinations every semester and now, with self sponsored programmes, the examination processing units have become a beehive of activities as draft examinations are submitted, typeset, proof read and packaged. A pool of copy typists is ever busy converting handwritten exam scripts into printable examination question papers, which in most cases are just re-organized questions from past papers. There are other times when an examination is required and the typesetting is not yet done or the examiner is not even available to provide the original copy for typesetting. Special and Supplementary examinations creates another nightmare especially when notice is too short.

Many are the times when examiners are not able to prepare standard papers due to their busy schedule. Sometimes they are out of reach and a person who may not have taught the subject is called upon to provide a draft examination. This paper gives an overview of the main design, working and possible implementation of a DYNEXAM software system, which was developed, with the aim of addressing the issues described above. Some illustrations are also provided based on existing templates.

2.0 Background Information

Many attempts have been made to automate exam generation but success has been limited to electronic versions. By electronic we mean examinations that must be done on the computer with minimal typing of any answers. Examinations such as the ones based on Cisco and Microsoft certifications are mostly of this nature. Since the learner is only supposed to pick the correct answer from a given set of options, most learners only visit question dump sites (www.ciscoexams.org/passguide-cisco-exam/), www.examsguide.com/mcse/mcsemockexams.html) and access the questions prior to their examinations. With repeated runs, one is assured of coming across some of the pre-available questions. With subjective questions for the traditional setup, such sites may not prove very useful, as the learner may be required to tackle essay type of questions. A good number of software tools exist online. For example Takshila Software for examination is ideal software to process examination related activities, (http://www.takshila.org/software.htm). A recent attempt has been made by Bettina and Zeileis (2009) to automatically generate exams using R software but most of the examinations so generated are not for print.

3.0 Design

The proposed system is an integration of several Information Technology Tools and principles to create an examination generation engine or system. The system can run on a stand alone computer but an intranet in an examination office could be ideal. The main software tools required are:

At processing phase

(i) LATEX (Scientific open source typesetting software)
(ii) YACAS (Yet Another Computer Algebra Software)-free
(iii) JAVA

At output phase

(i) The Acrobat reader which acts as the viewer for the generated PDF papers
(ii) Web Browser-Mozilla for the online version

At both phases

(i) One can use the system with Windows system or Linux
(ii) Operating systems (Linux is free)
(iii) XAMPP which brings with it Apache Web Server and MySQL database for the online version.

The main input by the user is the typesetting of the questions together with their answers and then placing them in a database (questions bank). The database is either a large latex file containing all the possible questions covering the whole syllabus or small latex files each containing one question. The small file could have more than one question if it they must always appear together be together in any given examination paper.

3.1 Typesetting the Questions for System

LaTeX is a document markup language and document preparation system for the TeX typesetting program developed by Leslie Lamport (1980). The term LaTeX refers only to the language in which documents are written, not to the editor used to write those documents. In order to create a document in LaTeX, a .tex file must be created using some form of text editor such as WinEdit, LyX, TexnicCenter. Latex works with special instruction files called packages. A good reference to the typesetting rules can be be found online, see Roberts (2009). One such package is the Answer.sty, which is standard latex package, which specifies the rules and environments for typesetting questions with solutions after the document. For example: For every question provide the answer placed between the codes \begin{solution} and \end{solution}. A code that governs the random selection is placed just before the particular question. The code is written using YACAS programming language which when passed through JAVA interpreter is executed to determine whether the question is picked or not. The format for typesetting is

CODE ⟶ QUESTION ⟶ ANSWER

Example

CODE Who is the first president of Kenya \begin{solution} Mzee Jomo Kenyatta \end{solution}.

The code, question and answer must be in one line or paragraph otherwise the same code must be placed in each line which is a part of the question.

The coded file will normally contain latex deactivated questions. If an attempt is made to compile it without following the standard link, a blank PDF file is produced (it could contain the caption but no questions). When the processing is requested by clicking a batch (.bat) file or a link to it, new file is created in which all the selected questions are activated. The randomness is ensured by use of time difference in re-computing the random seed using server time in milliseconds. The new file is then compiled using latex builder in the standard way to give a portable document format (PDF) file, which is viewable using freely provided acrobat viewer. In the case of the online version, a download link becomes available at the users side once the processing is complete. On clicking it, the PDF file so produced opens.

4. 0 Implementation

The Chief Examinations Officer administers the system by ensuring that only authorized persons (examiners) have user accounts. A unit examiner walks in to the examination office, logs in, clicks the link to the unit examination unit and peruses through the generated test/examination. If he/she is not satisfied by the exam questions randomly selected, he clicks on the link again and another set of questions is generated. When satisfied with the generated exam, he/she sends it to the printer and fills the proofreading forms. He/she carries a copy of the examination answers (marking scheme) leaving the question paper being processed.

The screen capture in Fig 1 below displays the front page of the system. After user log on, basic user information and a log file for data control are saved in a database on the web server.

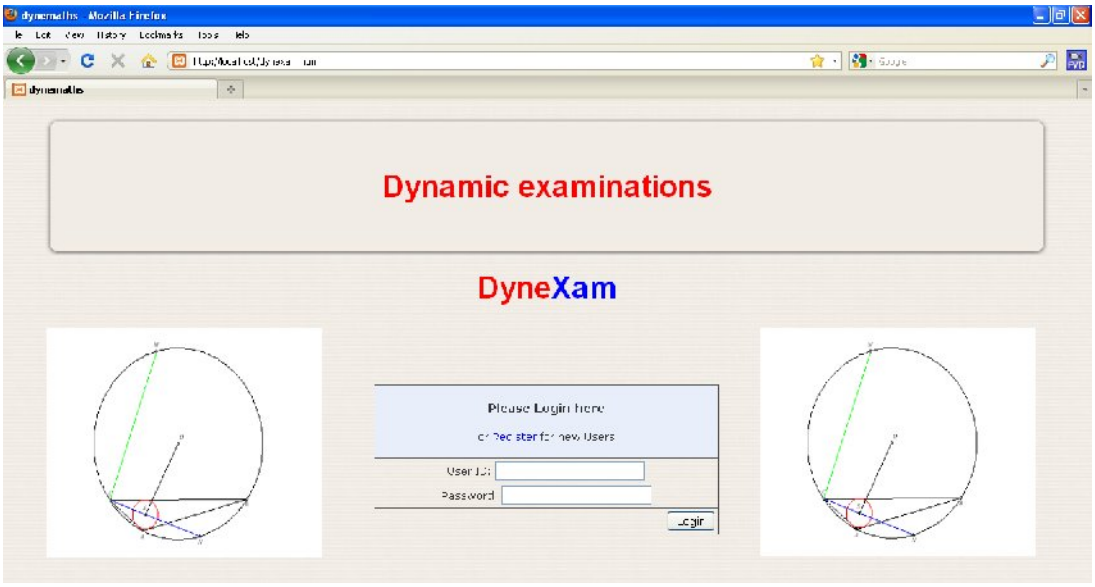


Figure 1: Login page

After some few seconds, the following screen appears. It contains the links to all the questions, which can be quizzes, CAT's 1-3 or the Main Exam. The current sample system has five units, up to three CAT's and the examinations for each. A user can choose the testing option by weakness of a topic or generally for revision.

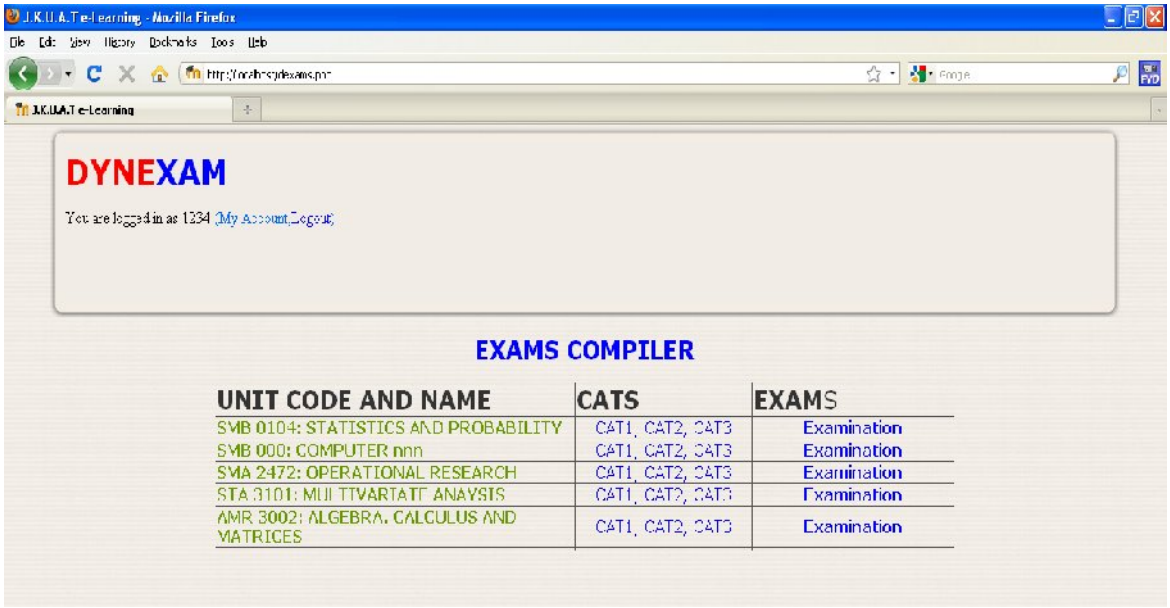


Figure 2: Page with links to examination

The next thing is to click on the selected exam and wait for it to be compiled. This is where the system engine is engaged since it randomly calls the questions from a Latex file and then compiles them and outputs them together with the solutions in a PDF file. A page appears which has only a tab, which is linked, to the PDF file that has been generated.

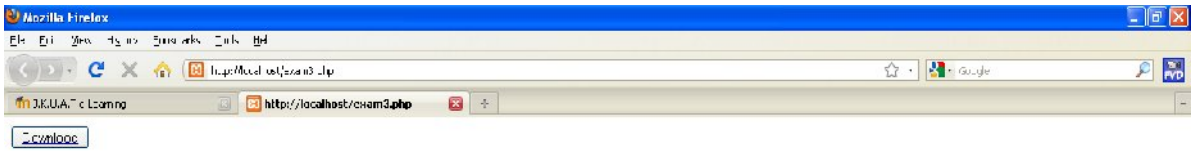


Figure 3: Page that has the download linked tab

After clicking on the link, a page opens on the same window which displays the date and time the exam was generated.

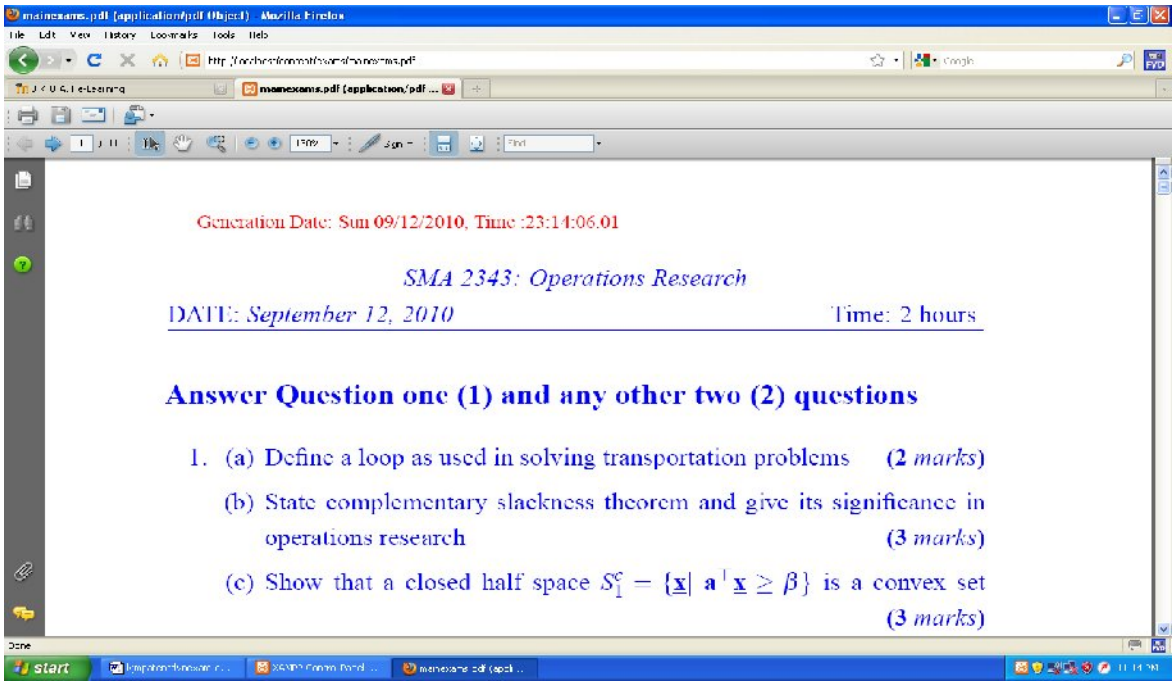


Figure 4: The downloaded examination in PDF

Every time the Download Tab link is clicked, it generates a different set of questions.

a)

Generation Date: Sun 09/12/2010, Time :7:48:01.53

SMA 2343: Operations Research

DATE: *September 12, 2010* Time: 2 hours

Answer Question one (1) and any other two (2) questions

1. (a) State the optimality and feasibility conditions as used in simplex algorithm of solving LP problems **(2 *marks*)**

   (b) Define a convex combination of points $x_1, x_2, ..., x_n$ in a convex $C \in \mathbf{R}^n$ and show that a set of convex combinations is also convex **(4 *marks*)**

b)

Generation Date: Sun 09/12/2010, Time :7:48:08.68

SMA 2343: Operations Research

DATE: *September 12, 2010* Time: 2 hours

Answer Question one (1) and any other two (2) questions

1. (a) Define a loop as used in solving transportation problems **(2 *marks*)**

   (b) State duality theorem and explain briefly its significance in operations research **(3 *marks*)**

   (c) State the optimality and feasibility conditions as used in simplex al-

Fig. 6 (a) & (b): Two different screen captures of exam questions, the 2nd one having been generated after 7 seconds after the 1st one.

The answers will appear at the end of every question paper as shown below

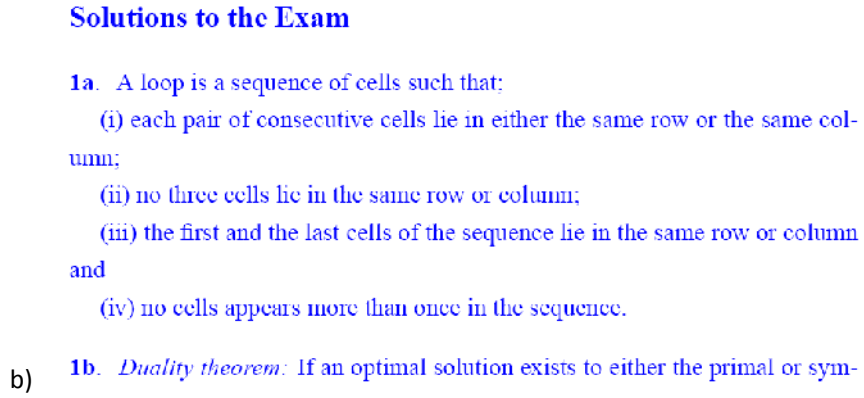
a)

Solutions to the Exam

1b. A point X is said to be a convex combination of $X_i (i = 1, 2, ..., n)$ if $X = \sum_{i=1}^{n} \alpha_i X_i$ where $\sum_{i=1}^{n} \alpha_i = 1$ and $\alpha_i \geq 0 \quad \forall i$

Let C be the set of all convex combinations of $X_1, X_2, ..., X_n$, let Y_1 and Y_2 be two points in C, then $Y_1 = \sum_{i=1}^{n} \alpha_i X_i$ and $Y_2 = \sum_{i=1}^{n} \beta_i X_i \qquad \sum \alpha_i = \sum \beta_i = 1 \qquad \alpha_i, \beta_i \geq 0$. Let X_0 be any point on the line segment joining Y_1 and Y_2, then X_0 can be written as $X_0 = \lambda Y_1 + (1 - \lambda) Y_2 \qquad \lambda \in (0, 1)$

$$\Rightarrow X_0 = \lambda Y_1 + (1 - \lambda) Y_2$$



Solutions to the Exam

1a. A loop is a sequence of cells such that:

(i) each pair of consecutive cells lie in either the same row or the same column;

(ii) no three cells lie in the same row or column;

(iii) the first and the last cells of the sequence lie in the same row or column and

(iv) no cells appears more than once in the sequence.

b) **1b**. *Duality theorem:* If an optimal solution exists to either the primal or sym-

Figure 7 (a) and (b): Two different screens capture solutions of the exam questions in Fig. 6 above

6.0 Conclusion

DYNEXAM is comes in time to solve real problems especially with the advent electronic learning, which operates, with the slogan of learning from anywhere anytime and any pace. This could mean demand for standard examination papers at anytime depending on the learners pace. All what an academic institution need to do is to place moderated questions in DYNEXAM and the rest will be a click away.

The issue of security concerns need not worry anybody because access to the system is password controlled in a local area network. Even if the system was to be accessible online, the only sure way that the learner has the leak to attempt all the questions in the database which is equivalent to covering the syllabus.

References

Grün, Bettina and Achim Zeileis (2009), `Automatic generation of exams in **R**', *Journal of Statistical Software* **29** (10), pp 1-14.

Lamport, Leslie (1980).`LaTeX'. **URL***: http://en.wikipedia.org/wiki/LaTeX*

Roberts, Andrew (2009), `Getting to grips with LaTeX'. **URL***: http://www.andyroberts.net/misc/latex/*

A FUZZY MODEL BASED ON SOFTWARE QUALITY METRICS WHICH ESTIMATES SOFTWARE MAINTAINABILITY

J. N. Gichuru[1], W. Mwangi[2] and M. Kanyaru[3]
[1,2]Institute of Conputer Science and information Technology, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[3]Software Systems Research Center, Bournemouth University, United Kingdom
E-mail: joangichuru@yahoo.com

Abstract
This study proposes a prediction model built on fuzzy logic technology to estimate the maintainability of a software product. This research is guided by two objectives: First is to establish the factors that determine software maintainability at source-code level and the metrics that capture these factors. Second is to establish a means of combining these metrics and weigh them against each other. The outcomes of these objectives are presented as well as a discussion of knowledge modeling using fuzzy logic. The development of this model is based on the fact that maintainability like other software quality facets can be described in terms of a hierarchy. This hierarchy consists of factors, attributes and metrics. The model captures factors that determine maintainability at source-code level as articulated by various attributes. Three metrics which quantify these attributes are then considered as input parameters to the model. These metrics are average cyclomatic complexity, average number of live variables and the average life span of variables. Fuzzy logic is then used to weigh the metrics against each other and combine them into one output value which is the estimated software maintainability. This work is a contribution to the on-going research aimed at establishing a means to quantify maintainability of software. It is also an improvement to the much criticized maintainability index (MI), the identified measure so far.

Keywords: Software maintainability, fuzzy logic, average cyclomatic complexity, average live variables, average variable span

1.0 Introduction

Software maintenance encompasses a broad range of activities including error corrections, enhancement of capabilities, deletion of obsolete capabilities and optimization (Lamb, 1988). Software maintainability is dependent on various factors ranging from personnel-skill, the environment of development, size and age of an application. In addition, program features at source-code level largely determine the maintainability of the resulting software. These features include the number of branches in a module, the degree to which a module calls other modules and the extent to which a module makes access to global variables (Sneed and Mercy, 1985).

Software maintenance occurs because software does not do what it was designed to do. Higher quality software is likely to require less maintenance. The need to improve the quality of software makes it necessary to have a way of quantitatively measuring quality and this is the realm of software quality metrics. Software quality metrics are a crucial tool when it comes to solving software maintenance problems. The metrics quantitatively measure aspects of a system which can be used as indications of the overall quality of a system (Elshoff, 1998).

The problem of maintaining software is widely acknowledged in industry and much has been written on how maintainability can be facilitated. However, you cannot control what you cannot measure and there is yet no universal measure of maintainability. Some proposals have indeed been presented, but the idea of measuring maintainability has inherent problems. Firstly, maintainability has mainly been described using informal descriptions e.g. the IEEE Standard Glossary of Software Engineering Terminology of 1990 defines maintainability as the ease with which a software system or component can be modified to correct faults, improve performance or other attributes, or adapt to a changed environment (IEEE, 1990). Measuring maintainability as “effort or ease” introduces a problem since the commonly known unit for effort is “man/months or man/hours”. Hence, informal definitions do not in any way guide in how to estimate or measure maintainability. The known measure of software maintainability so far is maintainability Index (MI) which also has notable gaps. MI is a composite metric that considers weighted Halstead metrics (effort or volume), McCabe’s Cyclomatic Complexity, lines of code (LOC) and number of comments (Stephen, 2003). Practically though, the involvement of comments in the MI has posed as a difficulty in understanding maintainability. This is because comments, just like source code, will degrade over time as maintenance activities are performed unless specific actions are taken to keep them from becoming inaccurate. Again, comments are not executed at run-time but are meant for people. Only people therefore can tell if the comments in the code are helpful or not hence their inclusion in code does not necessarily mean that the code is more maintainable.

ISO (2000) quality model describes maintainability as the set of attributes that bear on the effort needed to make specified modifications on software. Following this description, maintainability may be understood as a function of directly measurable attributes. This approach is practical especially when there are defined metrics to measure those attributes. However, there may be difficulty in weighting the measures against each other and combining them in a function. There are thus several issues surrounding estimation of software maintainability.

This paper proposes a model that uses three source-code level metrics namely average number of life variables, average life span of live variables and average Cyclomatic complexity. These three metrics will form the inputs to the model which by applying fuzzy logic will compute an estimate of the expected maintainability. These metrics reflect source-code level features that determine maintainability such as branching in modules, nature of variable access and interdependence.

2.0 Materials and Methods

2.1 Approach

The model follows the approach that maintainability is a function of directly measurable attributes as described by ISO (2000). These attributes are features of source-code that determine maintainability of the resulting software such as nature of branching in modules, variable access and inter-dependence of modules. These features will be captured using three defined metrics namely; average Cyclomatic complexity, average number of live variables and average span of variables which will form inputs to the proposed fuzzy model. Fuzzy logic will be used to weight the measures against each other and to combine them into one function. The model will thus have a single output which is the estimated maintainability of the program being evaluated.

2.2 Development Platform

These computations will be done using MATLAB while the design of the model will be implemented using Fuzzy Toolbox, an add-on tool in MATLAB. MATLAB is a high performance language for technical computing which integrates computation and programming. It makes use of mathematical notations to express the problems and solutions being modeled. It has several add-on toolboxes which are suited for various specialized technology. Among them is the Fuzzy Logic Toolbox which is a collection of functions built on the MATLAB technical computing environment. It enhances creation and editing of fuzzy inference systems within the framework of MATLAB.

2.3 Fuzzy Logic

Fuzzy logic is an innovative technology that enables one to describe a desired system behaviour using every day spoken language. It is a natural continuous logic that is patterned after the approximate reasoning of human beings. Approximate reasoning refers to processes by which imprecise conclusions are inferred from imprecise premises (Nguyen and Walker, 1999). The context in which theory of approximate reasoning is used is manifested by domain knowledge containing uncertainty and imprecision. When the domain knowledge contains fuzzy concepts and is expressed in a natural language, then fuzzy logic becomes an appropriate theory for modeling (Canfora et al., 1998). Unlike traditional or Boolean logic, it's not restricted to the conventional binary computer values of zero and one but it allows for partial truths and multi-valued truths. Fuzzy logic recognizes the advantages of approximate reasoning whereby in most real world situations, a precise answer does not necessarily provide an optimal solution. It is particularly useful for problems that cannot be easily represented by mathematical modeling because data is either unavailable, incomplete or the process is too complex.

2.4 Factors Affecting Software Maintainability

In software engineering, maintainability is defined as the ease with which a software product can be modified. A software product is modified in order to correct defects, meet new requirements, make future maintenance easier, or cope with a changed environment. These tasks are commonly known as software maintenance activities (Sommerville, 2006). Several factors determine the ease with which maintenance activities can be done. These factors include program features at source-code level, age and size of a product, the development environment, personnel-skill among others. Personnel skill means the presence of or lack of a trained maintenance team. It is easier when modifications to a product are done by staffs who developed it or who have interacted with it while in use rather than new staff. Large products may be harder to modify than smaller applications even though it is not always the case. The age of a product also determines its ease of modification. Old products that have gone through several changes degrade and become less maintainable as compared to new products (Sommerville, 2006).

This study focuses on features of source-code that may determine maintainability. These features include dependency or coupling among modules, pattern of variable access and code complexity.

Coupling is when one module modifies or relies on the internal workings of another module e.g. by accessing local data of another module (Daly et al., 1996). This usually implies that changing the second module will lead to changing the dependent module. It is harder to perform maintenance activities on tightly coupled program code since a change in one module usually forces a ripple-effect of changes in other modules. Secondly, when a variable is declared as global it means that it can be accessed from all scopes and hence any code anywhere in the program can change the value of the variable at any time. The use of global variables makes it more difficult to isolate units of code for purposes of modification or even unit testing. The values of global variables can also be changed by any function that is called, and there is no easy way for the programmer to know that this will happen. Global variables therefore have unlimited potential for creating mutual dependencies which in turn increases complexity in the languages that implement them. The complexity of code also affects its maintainability since to a large extent it reflects difficulty in comprehending the code. Code complexity is articulated by the nature of control flow of modules, the flow of data and even the data structures used. Control flow is a general concept relating to the order in which various instructions of a program are executed (Coleman *et al.*, 1994).

2.5 Metrics for the Study

Rombach has published the results of a carefully designed experiment that indicates that software complexity metrics can be used effectively to explain or predict the maintainability of software in a distributed computer system (Rombach, 1987). A set of three complexity metrics, each of which measures an aspect of structural complexity of a program code have been considered. These metrics are average number of live variables, average variable span (Peng and Dolores, 1994) and average cyclomatic complexity defined by McCabe (McCabe, 1976).

Live variable is a measure of data flow reflecting the number of variables whose values could change during the execution of a program. A variable is live at a particular statement if it is referenced by a certain number of statements before or after that statement (Peng and Dolores, 1994). The average number of live variables is therefore a ratio of the count of live variables and the count of executable statements. For example, in a section of code, the average number of live variables is the sum of the number of live variables for each line divided by the number of lines of code. The more the number of live variables, the more difficult it would be to develop and to maintain software.

Variable span is the number of source-code statements between successive references to a variable without consideration of comment lines (Peng & Dolores, 1994). For example, if a variable is referenced in lines 13, 18, 20, 21 and 23, the average span would be the sum of all spans divided by the count of spans, i.e., $(4 + 1 + 0 + 1)/4 = 1.5$. A large value for variable span reduces understandability and readability of code and a far back reference is likely to be missed out or forgotten.

Cyclomatic complexity also measures structural complexity and depicts the flow of control in a program. It considers decision points in a method or module which are implemented by use of conditional statements like if–else or while and logical operations such as AND, OR and NOT is defined as average of Cyclomatic complexities of all the modules (McCabe, 1976). Given any computer program, we can draw its control flow graph, G wherein each node corresponds to a block of sequential code and each arc corresponds to a branch or decision point in the program. The Cyclomatic complexity of such a graph can be computed by a simple formula from graph theory; $( ) = \quad - \quad + 2$ where is number of edges, and is the number of nodes in the graph. Cyclomatic complexity has enormous impact on the testability and maintain-ability of code. If the Cyclomatic complexity value increases, there is an increasing number of decision points within the code and this means more effort to test the method.

2.6 Procedure

This section describes a step by step detailed design of the fuzzy model. It entails the following four steps:

2.6.1 Definition of Linguistic Variables

The model will consider 3 input variables namely: average Cyclomatic complexity, average number of live variables and average span of a variable. In the design of the model, these variables will be denoted as CycCom, LivVar and VarSpan respectively. Each of these variables will be described using three linguistic terms namely Low, Medium and High. The model has one output variable namely maintainability denoted as MANT which will be described using five linguistic terms to give more precision to the output obtained. These terms are namely Very-low, Low, Medium, High and Very-high.

2.6.2 Definition of Membership Functions

Standard membership functions will be used due to their simplicity and ease of interpretation. These standard membership functions include Z-shaped, S-shaped and triangular-shaped membership functions named after the shape of their plots. (Canfora *et al*.,1998). The variables are fuzzified as shown in the figures below.

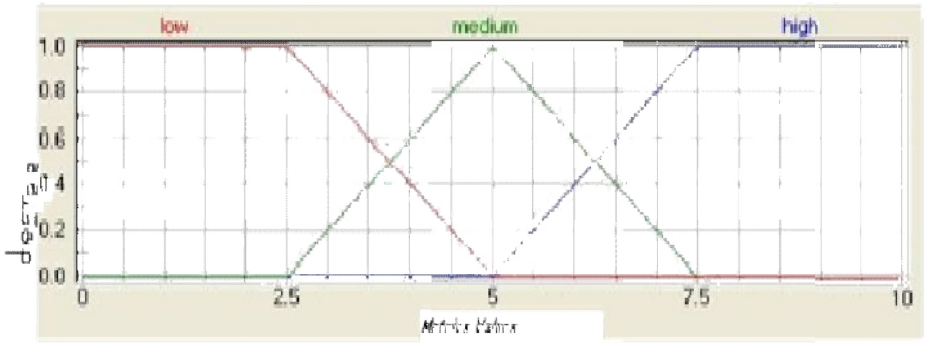


Figure 1: Fuzzification of cyclomatic complexity

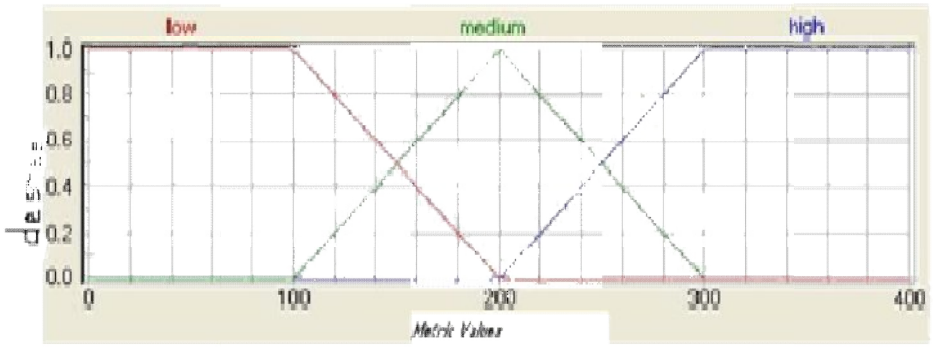


Figure 2: Fuzzification of variable span

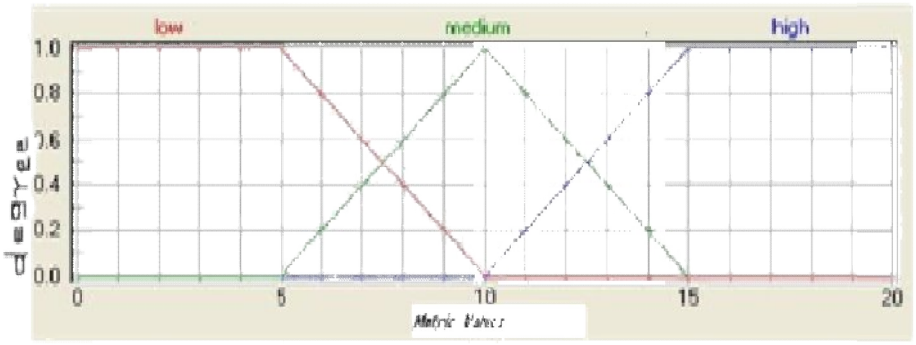


Figure 3: Fuzzification of count of live variables

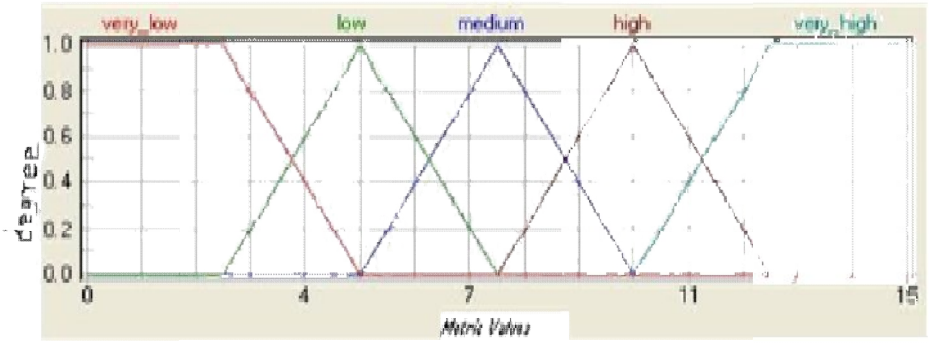


Figure 4: Fuzzification of maintainability

2.6.3 Creation of a Rule Base

A knowledge base or rule base consisting of 27 rules is created. This number is as a result of considering all the possible combinations of the three inputs i.e. 3^3 and a rule is assigned to each combination. The rules are expressed in verbose format where the number in the brackets represents the weight e.g.

If (Cyclomatic-Complexity is Low) and (Live-Variable is Low) and (Variable- Span is Low) then (Maintainability is very good) (1)

2.6.4 Selection of a Suitable Defuzzification Method

The choice of a defuzzification procedure is usually guided by considerations such as robustness or sensitivity to errors in its arguments. This research employs the centroid method sometimes called Center-of-Gravity method since its continuous on the space of membership functions hence tends to have good robust properties.

3.0 Results

Suppose we have the following inputs to the model as shown in the sample interface below: *CycCom*=2, *LivVar* =1 and VarSpan =130. When those inputs are fuzzified we find that *CycCom*=2 belongs to fuzzy set low with membership grade 1, *LivVar* =1 belongs to fuzzy set low with membership grade 1 and VarSpan =130 belongs to fuzzy set Medium with membership grade = 0.5 and medium with membership grade 0.5.With these inputs, rule 3 fires and an output value of 3 is obtained for MANT.

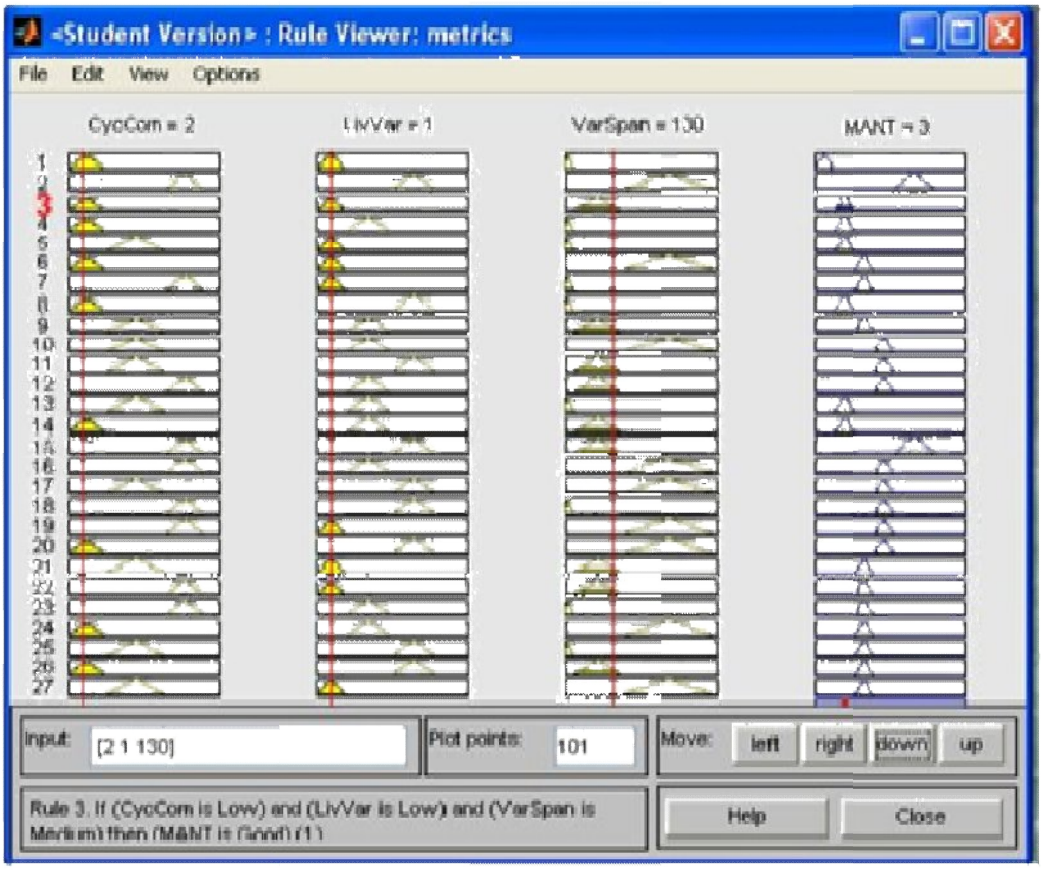


Figure 5: Model output computation

4.0 Discussion and Conclusions

To better understand these results, we look at maintainability as a software quality component that can be described in terms of a hierarchy. This hierarchy consists of factors, attributes and metrics. A factor is at the top-level and is an expression of the software status. Each factor is described by a set of attributes which can be measured by a set of metrics. In this view, the fuzzy model developed in this study is based on factors that affect software maintainability. These factors are articulated by measurable attributes that have been captured by the three metrics used. Since we understand how each metric has been defined and which attributes have been measured, then we increase our knowledge on the source-code process created and also the expected quality of that source code when placed into service. Parnas (2001) argued that the solution to the maintenance problems lies not in maintenance, but in development. Even during development, software is subject to constant change and revision. Use of prediction models is one among many software practices aimed at facilitating this and it is concluded from this study that fuzzy logic can be used to come up with a prediction model.

References

Aggarwal, K., Singh, Y., Chadra, P. and Puri, M. (2005). Measurement of software maintainability using fuzzy logic. *Journal of Computer Sciences*, **4**, pp 538–542.

Driankow, D., Hellendoorn H. and Reinfrank (1996). An Introduction to Fuzzy Control, 23–47. Springer-Verlag.

Daly, J., Brooks, A., Miller, J., Roper, M. and Wood, M. (1996). *Evaluating* inheritance depth on the maintainability of object-oriented software. *J. Empirical Software Engineering*, **1**, pp 109–132.

Elshoff, J. L. (1998). An investigation into the effects of counting method used on software science measures. *ACM SIGLPA Notices*, **13**,pp 30–45.

Kafura, D. and Reddy, G. (1987). The use of software quality metrics is software maintenance. In IEEE Trans. *Software Eng*., vol. **3**, 335–343.

McCabe, T. J. (1976). A complexity measure. IEEE Trans. *Software Eng., SE*-**2**, pp 308-319.

Nguyen, H. T. and Walker, E.A. (1999). A First Course in Fuzzy Logic, 67–76. Chapman Hall, 2nd edn.

Rombach, H. D. (1987). A controlled experiment on the impact of software structure on maintainability. In IEEE Trans. *Software Eng.,* vol. **3**, pp 344–354.

Sneed, H. AND Mercy, A. (1985). Automated software quality assurance. IEEE Trans. Software Engineering, 909–916.

Sommerville, I. (2006). *Software Engineering*, 9–23. Pearson Education, 7th edn.

Stephen, H. K. (2003). Metrics and Models in Software Quality Engineeing, 234–257. Pearson Education Inc., 2nd edn.

COMPUTER USAGE IN INSTITUTIONS OF HIGHER LEARNING: CASE OF JKUAT

M. J. Wafula, A. Kibe, B. Kiula, B. Mwirigi, C. Wambugu
Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya

Abstract
Universities worldwide are impressing adoption of computers in their operation and delivery of services. Enterprise Resource Planning systems (ERP) are among Management Information Systems (MIS) preferred for adoption. The adoption ensures optimization of ICT resources. JKUAT has implemented Sage ACCPAC ERP and in the process learnt lessons that can be shared. Through a survey conducted across the University, this paper sought to examine the effectiveness and correctness of computer usage at JKUAT. The findings of the survey pointed to the need of formulating a computer usage policy (CUP). The paper outlines the implications of operating without a computer usage policy.

Key words: Enterprise resource planning, information and communication technology, computer usage policy, management information system

1.0 Introduction

Policy statements explaining the correct and incorrect use of organizational information systems are thought to reduce the amount of misuse within an organization (Charles, B.F., Timothy P.C. & Thomas, W.J. 2005). Using written statements to reduce the occurrence of some undesirable action is based on the Theory of General Detterence (TGD) which suggests that punishing offenders will prevent others from committing the same action. According to TGD, University computer usage policies should reduce the occurrence of computer misuse.

Information systems misuse and computer crime is defined as: unauthorized, deliberate, and internally recognizable misuse of assets of the local organizational information system by individuals. Possible abuses include violations against: Hardware (and other physical assets associated with computers, such as theft or damage to terminals, CPUs, disk drives and printers): programs (such as theft or modification of programs); data (such as embezzlement or modification of data) and computer service (such as unauthorized use of service or purposeful interruption of service).

Misuse and computer crime is widespread and is increasing in frequency in organizations implying that they must contend with customer perception of lack of security which can result in lost revenue. Computer misuse attempts can be grouped as either coming from inside the organization or from outside the organization. However, exposure to the University computer usage policy (CUP) can result in a fairly large increase in awareness among staff and also exposure to the deterrents drastically increases awareness of the consequences of misuse.

An employee orientation program must include discussion of correct and incorrect computer usage, penalties for misuse, moral appeals, and methods of enforcement along with tougher enforcement policies. Information systems misuse and computer crime is a serious and ongoing problem and the problem remains very significant. Computer Usage Policies have been used as an attempt to curtail access to material deemed inappropriate for the work environment. (Breakey, 2007), and violations of these policies have resulted in dismissal of employees (Broadwater, 2007). It is noteworthy that staff who are more familiar with the University's computer usage policies are less likely to conduct an act that would violate these policies.

Aspects of computer use can be assessed through three main dimensions. These are: the extent of functional use of computers; the frequency of use of computers and the degree of dependency on computers.

These refer to the degree to which staff work activities rely on the availability of computer facilities. Hence increased computer usage in different functions affects job satisfaction to a different degree. The amount of training and easy access to a computer have been reported to be the most important factors related to computer use.

The study was carried out with the aims to surveying on computer usage at Jomo Kenyatta University of Agriculture and Technology. It complements the efforts of the Information and Communication Technology (ICT) Directorate performance on proper computer usage in the University's departments.

2.0 Materials and Methods

Members of staff at the University were contacted through their respective Heads of Departments where they serve. The staffs were asked to complete a questionnaire regarding their awareness of University Computer Usage. Forty Two (42) departments responded to the questionnaire. The data was captured and analyzed for the purpose of this report.

3.0 Results

It emerged that almost all members of staff have computers of which most of them are connected to the internet. This indicates that the ICT Directorate's effort in establishing, spreading and supporting the LAN (Local Area Network) /WAN (Wide Area Network) /Internet infrastructure is by far and large bearing fruit.

Search engines have been properly utilized in that majority of the people are able to access scholarly journals and fill government forms. However, there is still a group of employees who use the search engine to do their personal assignments, search for job opportunities and participate in blogs.

Majority of the respondents use the internet as a research and a communication tool. In addition, there are other activities that the employees achieve using the internet; they range from social networking, commerce News and weather reports. No staff spends a day without access to internet and none spends a whole day on Internet. This could indicate that staff strike a balance overuse and underuse with an equivalent number using it more than 1 hour a day and not more than I hour a day.

It was noted that a significant majority of internet users use it for research and email. This is seen as a key driver towards the achievement of a university of global excellence in training, research and innovation for development while also utilizing less paper/ physical and more electronic means (electronic)

It was noted that a significant majority of the respondents utilize search engines to access scholarly journal and government forms. This is a strong indicator of sound use of computing facilities for scholarly purposes. On the other hand, and in line with the Kenya Vision 2030 a significant majority is turning to internet facilities to access government services.

The uses of information search apparent here is search of information on goods and services, on health and nutrition, communication on JKUAT email, reading and downloading all of which can be considered noble and inline with the university.

Upon intrusion, the information lost by the university would be more than 50%. This means that should there be a problem then, most of the University's operations would be halted due to the loss.

Majority of the respondents preferred Yahoo mail to the JKUAT mail. This poses a need to improve on the University's email so that more people utilize it. If properly utilized, the JKUAT mail is faster and more convenient to access than any other mail.

An element of awareness and skill verses preference is notable. With Yahoo mail and JKUAT mail being well known and the most preferred unlike the newcomers such as *@gmail.com* and Excite mail despite near similar functionality.

Effort is thus needed to useful systems and raise awareness and skill for increased acceptance and preference.

4.0 Recommendation

There is need for a scheduled backup of the information to ensure business continuity when loss strikes. On the other hand, the more than 40% personal information loss indicates that there is a lot of personal information being stored in the university's resources.

There would be a loss of more than 60% by the university and departments incase of intrusion. About a third (1/3) would lose vital personal information which means that mechanisms need to be in place: to protect JKUAT information resources; reduce presence of personal information on JKUAT ICT infrastructure and enhance infrastructure and policy enhancement for the short and long term protection of JKUAT information resources.

5.0 Conclusion

This study notes that the implementation of computer usage policies within the university would ensure that all users are familiar with the content of those policies and the penalties imposed for their violation. A backup schedule should also be put in place to protect the data stored on computers and a well understood procedure should be used for backup.

BOOTSTRAP UNIFORM CONFIDENCE BANDS FOR A LOCAL LINEAR NONPARAMETRIC ESTIMATOR AND APPLICATIONS TO FINANCIAL RISK MANAGEMENT

O. K. Ananda[1], P. N. Mwita[2]
Department of Statistics and Actuarial Sciences, Jomo Kenyatta University of Agriculture and Technology, Naiorbi, Kenya

Abstract
This paper considers the problem of bootstrapping a local linear estimator in conditional quantile estimation of a financial time series assuming independent and identically distributed errors. A nonparametric regression bootstrap generating process is estimated, then bootstrap confidence bands fitted to the quantile estimates. Under appropriate assumptions, the local linear bootstrap estimator is known to be consistent.

Key words: Quantile estimation, bootstrap, local linear, consistency

1.0 Introduction

Consider a partitioned stationary α-mixing time series (X_{t+1}, ξ_t) where the real valued response variable $X_{t+1} \in \Re$ is F_{t+1} measurable and the variate $\xi_t \in \Re^P$ which is F_{t-} measurable. For some $0 < \theta < 1$, we are interested in estimating the conditional θ quantile of X_{t+1} given the filtration F_t, and assuming that it is completely determined by ξ_t , we can consider the model:

$$X_t = f(X_{t-1}) + s(X_{t-1})\xi_t \qquad t = 1,2,3,... \qquad 1.1$$

Here the innovations ξ_t are assumed to be iid random variables with $E(\xi_t) = 0$ and $E(\xi_t^2) = 1$. Under these assumptions it holds that:

$$\begin{aligned} E(X_t / X_{t-1} = x) &= f(x) + E[s(X_{t-1})\xi_t / X_{t-1})] \\ &= f(x) + s(x)E(\xi_t) \\ &= f(x) \end{aligned} \qquad 1.2$$

A similar calculation gives $s^2(x) = \mathrm{var}(X_t / X_{t-1} = x)$. The unknown functions f and s describe the conditional mean and the conditional volatility of the process, which we want to estimate. We have developed a nonparametric regression methodology that will help estimate the values of s and f as shown above.

Nadaraya (1964) and Watson (1964) discussed a kernel smoothing for the nonparametric estimator function of f and s as in the model equation (1.1) above. Assuming finite moments of up to order 4, Franke & Wenzel (1992) and Kreutzberger (1993) proposed an autoregression bootstrap re-sampling scheme that approximates the laws of a kernel estimator for f and s. Franke et. al (2002) considered two estimators for the estimation of conditional variance and gave consistency of the residual based and Wild bootstrap procedures for f and s.

Although the model errors in model equation (1.1) are homoscedastic, we'll followed similar lines as in Franke et. al. (2002) for bootstrapping f and s. We also developed uniform confidence bands to give an idea about the global variability of the estimate from the model equation (1.1) since it's clear that curve of fit contains the lack of fit test as an immediate application. Hardle and Song (2010) used strong approximation of empirical process and extreme value theory to construct the uniform band over the estimator; however the poor convergence of the extremes of a sequence of n independent normal random variables is also investigated by Fisher and Tippet (1928). The slow convergence of kernel estimators as identified by Pritsker (1998) is the main reasons for the poor finite sample performance. In their write up, the casted doubt in the applicability of first order asymptotic theory of nonparametric methods in finance, since persistent serial dependence is a stylized fact for interest rates and many other high frequency financial data. Another fact is that a kernel estimate produces biased estimates near the boundaries of the data as discussed by Hardle (1990) and Fan and Gijbels (1996). Boundary bias can generate spurious nonlinear drift, giving misleading conclusions of the dynamics of X_{t+1}. Recently, Hong & Li (2002) have developed a nonparametric test for the model using the transition density, which can capture the full dynamics of X_{t+1}. It has been suggested that to avoid the boundary bias then kernel smoothing can be applied by methods of local polynomial Fan and Gijbels (1996) or a weighted Nadaraya Watson kernel estimator Cai (2001)

2.0 The Local Linear Estimator

The local estimation of $\mu(x)$ means estimating $\mu(.)$ separately for each $(m \times 1)$ vector $x = (x_1, x_2, ..., x_m)'$ of interest. Note that x is scalar if $m = 1$ and x_t is scalar. The starting point for deriving the local linear estimator is the fact that, although $\mu(x)$ is not observable, it appears in a first-order Taylor expansion of $\mu(x)$ taken at x

$$\mu(x_t) = \mu(x) + \frac{\partial \mu(x)}{\partial x'}(x_t - x) + R(x_t, x) \qquad 1.5$$

Where $R(x_t, x)$ denotes the remainder term. Inserting this expansion into the model equation (1.1) the gives

$$y_t = \mu(x)I + \frac{\partial \mu(x)}{\partial x'}(x_t - x) + R(x_t, x) + \xi_t \qquad 1.6$$

where the ξ_t denotes the stochastic error term.

The right hand side contains two known terms, the constant one multiplied by the unknown $\mu(x)$ and the known term $(x_t - x)$ multiplied by a vector of unknown first partial derivatives $\frac{\partial \mu(x)}{\partial x'}$ i.e. were there no remainder term $R(x_t, x)$, one would have a simple OLS regression problem in which the estimated parameters correspond to the estimated function value $\hat{\mu}(x)$ at x and the estimated vector corresponds to the estimated function value $\overline{\mu}(x)$ at x and the estimated vector $\frac{\hat{\partial}\mu(x)}{\partial x'}$ of partial derivatives also evaluated at x. However, whenever the conditional mean function is non-linear, the remainder term $R(x_t, x)$ maybe nonzero at x. Using the standard OLS estimation would then result into biased estimates for which the size of bias depends on all remainder terms $R(x_t, x)$, $t = 1,2,3, \ldots, T$. One possibility to reduce the bias is to use only those observations x_t that are in some sense close to x. More generally, one down-weighs those observations that are not in a local neighborhood of x. If more data is available, it is possible to decrease the size of the local neighborhood, where the estimation variance and bias can decrease, i.e. the approximation error of the model can decline with sample size. Thus the underlying idea of nonparametric estimation.

The weighing is controlled by a so called kernel function $K(u)$ where the following we can assume the function is symmetrical, compact, non-negative univariate probability density so that $\int K(u)du = 1$. To adjust the size of the neighborhood one introduces a bandwidth h such that for a scalar x the kernel function becomes $\frac{1}{h}K(\frac{x_t - x}{h})$. So the larger the value of h the larger the neighborhood around x, where the sample observations receive a larger weight and the larger may be the estimation bias. Because a larger h implies function estimates will look smoother, the bandwidth h is called the smoothing parameter. Since the observations in the local neighborhood of x are the most important, this estimation approach is called local estimation. If $m > 1$ and $x = (x_1, x_2, \ldots, x_m)'$ is a vector, one uses a product kernel

$$K_h(x_t - x) = \prod_{i=1}^{m} \frac{1}{h^m} K\left(\frac{x_{ti} - x_i}{h}\right) \qquad 1.7$$

Here the component x_{ti} denotes the i[th] component of x_t. Instead of using a scalar bandwidth that imposes the same degree of smoothing in all directions, it is also possible to use a vector bandwidth that determines the amount of smoothing in each direction separately. The kernel variance can be given to as $\sigma_k^2 = \|K\|_2^{2m} = \int u^2 K(u)du$ and the kernel constant $\int K(u)^2 du$ both influence the asymptotic behavior of the local linear estimator.

Owing to the introduction of the kernel function, one has to solve a weighted least-squares problem

$$[\hat{c}_1, \hat{c}_2, \ldots, \hat{c}_m] = \arg\min_{\hat{c}_1, \hat{c}_2, \ldots, \hat{c}_m} \sum_{t=i_m+1}^{T} \left\{ y_t - c - \sum_{i=1}^{m} c_i (x_{ti} - x_i) \right\}^2 K_h(x_t - x) \qquad 1.8$$

which delivers the local linear function estimate $\hat{\mu}(x,h)=\hat{c}$ at the point x.
The bandwidth h is also included as an argument to indicate the dependence method for bandwidth choice, which is based on statistical procedures. A well grounded bandwidth is also necessary for valid asymptotic properties of these estimators.

3.0 Asymptotic Properties of the Local Linear Estimator

Let $f(x)$ denote the density of the lag vector at the point x and $tr(A)$ - the trace of matrix A. The asymptotic normal distribution of local linear estimator is given by:

$$\sqrt{Th^m}\left\{\hat{\mu}(x,h)-\mu(x)-b(x)h^2\right\}\xrightarrow{d}N(0,v(x)) \qquad 1.9$$

Where the asymptotic bias $b(x)$ and asymptotic variance $v(x)$ which can be given as:

$$b(x)=\frac{\sigma_K^2}{2}tr\left(\frac{\partial^2\mu(x)}{\partial x\partial x'}\right) \qquad 2.0$$

$$v(x)=\frac{\sigma^2(x)\|K\|_2^{2m}}{f(x)} \qquad 2.1$$

This then becomes clear that, for the asymptotic normal distribution to exist, one has to require that $Th^m\longrightarrow\infty$ and $h\longrightarrow 0$ as $T\longrightarrow\infty$. Otherwise, the asymptotic distribution would collapse to a point or the bias would grow infinitely large. Inspecting the asymptotic bias term (1.9) more closely reveals that the second order partial derivatives of $\mu(x)$ have to exist. In fact for (2.1) to hold this has to be the case in a neighborhood of x hence one has to assume $\mu(.)$ is twice continuously differentiable on the support of $f(x)$. Because both the density $f(x)$ and the conditional variance $\sigma^2(x)$ enter the asymptotic variance (2.1), one also has to assume that both are continuous and the latter is positive on the support of $f(x)$. Initially the asymptotic distribution (1.9) was derived under the assumption that $\{y_t,x_t\}$ is a sample of i.i.d observations. Then x_t does not contain lags of y_t and there is no stochastic dependence between observations at different times. In the current situation, where x_t is a vector of lagged $y_t's$, a stochastic dependence clearly exists. Hadle & Yang (1998) showed that the asymptotic behavior of the local linear estimator (1.8) is the same as that encountered in the case of i.i.d variables if the stochastic dependence is sufficiently weak. At this point, it is sufficient to state that a stationary $ARMA(p,q)$ process satisfies the required conditions if its driving error process is not completely ill-behaved. For empirical work, it is most important to transform a given time series to be stationary. Thus prior to local linear estimation, one has to remove unit roots.
Some consequences of the implications of the asymptotic normal distribution can be given as:

$$\hat{\mu}(x,h)\approx N\left((\mu(x)+b(x)h^2,\frac{1}{Th^m}v(x)\right) \qquad 2.2$$

This nicely shows the asymptotic bias-variance trade-off. If h gets larger, the bias increases but the variance diminishes and vice versa. This asymptotic trade off will be used to obtain an asymptotically optimal bandwidth. By inspecting the formulae below that its rate of decline is $T^{-\frac{1}{(m+4)}}$, thus if we denote a positive constant by β, any bandwidth for which $h=\beta T^{-\frac{1}{(m+4)}}$, hold has the optimal rate

to guarantee a balanced decline of bias and variance. Inserting, $h = \beta T^{-\frac{1}{(m+4)}}$ into (1.9) delivers the rate of convergence of the local linear estimator with respect to the number of observations T that is:

$$T^{\frac{2}{(m+4)}}\{\hat{\mu}(x,h) - \mu(x)\} \longrightarrow N\left(b(x)\beta^2, \frac{1}{\beta^m} v(x)\right) \qquad 2.3$$

It becomes apparent that the rate of convergence of the local linear estimator depends on the number m of lags and becomes quite slow if there are many lags, often called the curse of dimensionality of nonparametric estimators. Note that the rate of convergence is slower than for parametric estimators even if $m = 1$. This is the price one pays in nonparametric estimation for allowing the model complexity to increase with number of observations and thus to let the bias reduce with sample size. Such an increase in model complexity is in general not possible if one wants to obtain the parametric $\sqrt{T}$ rate.

By inspection, (2.0) one can see that the estimation bias also depends on the second partial derivative of the conditional mean function as well as on the kernel variance σ_K^2. The asymptotic variance (2.1) increases with conditional variance $\sigma^2(x)$ and decreases with the density $f(x)$. The intuition for the latter is that the larger the density, the more observations are on average close to the point x and thus available for local estimation, which in turn reduces the estimation variance.

4.0 Bandwidth and Lag Selection

The method for nonparametric bandwidth and lag selection described here is based on Tscherning & Yang (2000). For a lag selection it is necessary to specify a set of possible lag vectors a priori by choosing the maximal lag M. Denote the full lag vector containing all the lags up to M by $y_{t,M} = (x_{t-1}, x_{t-2}, ..., x_{t-M})'$. The lag selection task is now to eliminate from the full lag vector $y_{t,M}$ all lags that are redundant. This depends on choosing a relevant optimality criterion. A widely used criterion is the mean integrated squared error of prediction commonly known as final prediction error (FPE). We state it by using a weight function $w(.)$ needed for obtaining consistency of the lag selection procedure. One has to choose a weight function $w(.)$ that is continuous and non negative and for which $f(x_M) > 0$ for x_M in the support of $w(.)$. The simplest example is the indicator function.

$$C = \int \left(tr\left[\frac{\partial^2 \mu(x)}{\partial x \partial x'} \right] \right)^2 w(y_M) f(y_M) dy_M = E\left(\left(tr\left\{ \frac{\partial^2 \mu(x)}{\partial x \partial x'} \right\} \right)^2 w(y_{t,M}) \right) \qquad 2.4$$

And $b(h) = \|K\|_2^{2m} (T - i_m)^{-1} h^{-m}$ and $c(h) = \sigma_K^4 h^4 / 4$,

And $b(h)$ and $c(h)$ depend on the bandwidth and kernel constants.

The integrated variance of estimation and the integrant squared bias of estimation go to 0 for increasing sample size if $h \longrightarrow 0$ and $Th^m \longrightarrow \infty$ as $T \longrightarrow \infty$ holds.

5.0 Bandwidth Estimation

For minimizing the AFPE with respect to h, i.e. by solving the variance bias tradeoff between $b(h)B$ and $c(h)C$, one obtains the asymptotically optimal bandwidth:

$$h_{opt} = \left\{ \frac{m \left\| K \right\|_2^{2m} B}{(T - i_m)\sigma_K^4 C} \right\}^{\frac{1}{(m+4)}} \qquad 2.5$$

In order for the optimal bandwidth to be finite, one has to assume that C defined is positive and finite. This requirement implies that, in the case of local linear estimation, an asymptotically optimal bandwidth h_{opt} for linear processes that is finite doesn't exist. This is because a first order approximation bias doe not exist, and thus a larger bandwidth has no cost i.e. clearly one should take a bandwidth as large as possible. It should be noted that h_{opt} is asymptotically optimal on the range where the weight function $w(.)$ is positive. For this reason it is also called the global asymptotically optimal bandwidth. Starting from the mean squared error of prediction:

$$\int \left[\int (\tilde{x} - \hat{\mu}(x,h))^2 f\left(\frac{\tilde{x}}{y}\right) d\tilde{x} \right] f(x_1,..., x_T) dx_1,..., dx_T \qquad 2.6$$

which is computed at a given x, one would obtain a local asymptotically optimal bandwidth, which, by construction may vary with x If h_{opt} is estimated by consistent estimators for the unknown constants B and C, the resulting bandwidth estimate is known as plug-in bandwidth $\hat{h}_{opt}$. One way to estimate the expected value B consistently is given by averaging the weighted squared errors from the local linear estimates:

$$\hat{B}(h_B) = \frac{\frac{1}{T - i_m} \sum_{t=i_m+1}^{T} \{x_t - \hat{\mu}(x_t, h_B)\}^2 w(x_t, M)}{\hat{f}(y_t, h_B)} \qquad 2.7$$

Where, $\hat{f}(.)$ is the Gaussian kernel estimator of the density $f(y)$.
Estimating h_B, one has to use Silverman's rule of thumb bandwidth Silverman (1986)

$$\hat{h}_B = \hat{\sigma}\left(\frac{4}{m+2}\right)^{\frac{1}{(m+4)}} T^{-\frac{1}{(m+4)}} \qquad 2.8$$

With $\hat{\sigma} = \left(\prod_{i=1}^{m} \sqrt{\text{var}(x_{ti})} \right)^{\frac{1}{m}}$ which denotes the geometric mean of the standard deviation of the regressors.
An estimator of C is give by

$$\hat{C}(h_C) = \frac{1}{T - i_m} \sum_{t=i_m+1}^{T} \left[\sum_{j=1}^{m} \hat{\mu}^{(jj)}(x_t, h_C) \right]^2 w(x_t, M) \qquad 2.9$$

Where $\hat{\mu}^{(jj)}(.)$ denotes the second order direct derivative of the function $\mu(.)$ with respect to x_{ti}. For estimating higher order derivatives, one can use local polynomial estimation of appropriate order. In estimating second order direct derivatives it is sufficient to use the direct local quadratic estimator:

$$[\hat{c}_0, \hat{c}_{11}, ..., \hat{c}_{1m}, \hat{c}_{21}, ..., \hat{c}_{2m}] = \arg\min_{\hat{c}_0, \hat{c}_{11}, ..., \hat{c}_{1m}, \hat{c}_{21}, ..., \hat{c}_{2m}}$$

$$\sum_{t=i_m+1}^{T} \{x_t - c_0 - c_{11}(y_{t1} - y_1) - ... - c_{1m}(y_{tm} - y_m) - c_{21}(y_{tm} - y_m)^2 - ... - c_{2m}(y_{tm} - y_m)^2\}^2 K_h(y_t - y) \quad 3.0$$

The estimation of the direct second derivatives are then given by $\hat{\mu}^{(jj)}(x_t, h) = 2\hat{c}_{2j}, \ \mathrm{j} = 1, ..., \mathrm{m}$. Excluding all cross term does not affect the convergence rate while keeping the increase in the parameters $c_0, c_{1j}, c_{2j}, \quad \mathrm{j} = 1, .., \mathrm{m}$ linear in the number of lags m. This approach is a partial cubic estimator proposed by Yang & Tschernig (1999), who also showed that the rule-of-thumb bandwidth:

$$\hat{h}_C = 2\hat{\sigma}\left(\frac{4}{m+4}\right)^{\frac{1}{(m+6)}} T^{-\frac{1}{(m+6)}} \quad 3.1$$

Has the optimal rate. The plug-in bandwidth

$$\hat{h}_{opt} = \left\{\frac{m\|K\|_2^{2m}\hat{B}(\hat{h}_B)}{(T - i_m)\hat{C}(\hat{h}_C)\sigma_K^4}\right\} \quad 3.2$$

6.0 Results and Discussions

Clearly the returns of the financial time series process can be seen to be normally distributed as shown in the Figure 1 below.

For such a process, then fitting a polynomial by a plug –in approach, the function that appears in the diagram gives an asymptotically optimal bandwidth best approximated with a local linear polynomial.

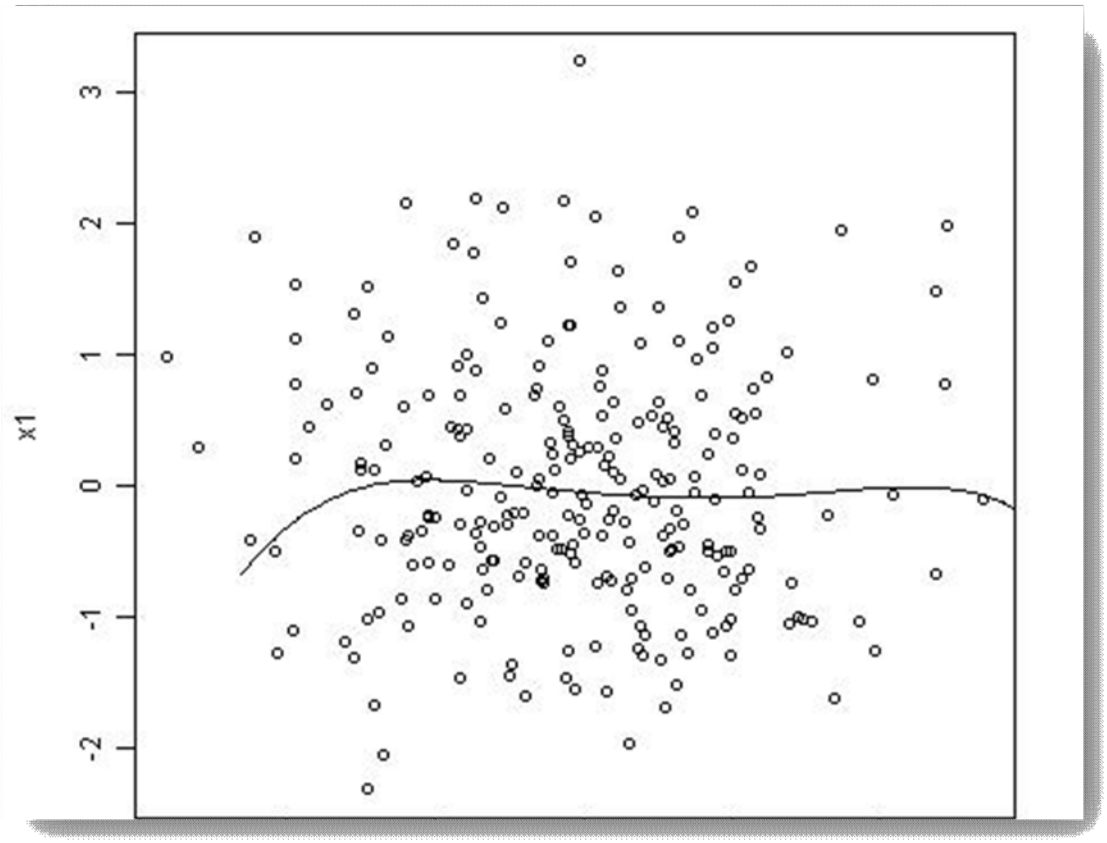


Figure 26: Returns of a financial time series

Fitting our returns data with a linear model with 2 coefficients (AR [1] process) for 250 training points produced the coefficients 0.9817942 that represented the y intercept and a gradient of 0.9727030. Hence the hypothesized model could be represented as $y = 0.9817942 + 0.9727030x$ where x represents the returns and y as the actual financial time series. The estimates for the standard errors for the coefficient above respectively gave 0.06867458 and 0.06262530 as the best variance bounds.

Again, fitting our returns data with a nonparametric regression local linear estimator to 250 training points to 2 variable(s) for 2 nonparametric regressor(s) using optimal bandwidth as given below.

Table 5: A table of optimal bandwidth and coefficients of a local linear polynomial on 250 points

	y	
Bandwidth(s): 0.1896613		0.3412962
	x	
Bandwidth(s): 0.001552832		0.7407379
0.999803300		0.2324291
	f	s
Coefficient(s):	0.9476291	0.958792
Residual standard error: 0.977513		
R-squared: 0.7270775		

Using the estimators fitted in the previous discussion, then the diagrams as shown below illustrate the power of local linear compared to the linear ordinary regression in trying to uncover the data generating mechanism for the returns data. As we can see, the vector of the bandwidth enables us to smooth the local linear estimator in all directions not necessarily equal but essentially uniformly at various values of the function. The final prediction error can be seen to be equals to 0.977513 and a coefficient of multiple determination of 0.7270775 that implies 73% of the returns are taken care of by the local linear estimator as the optimal lag vector. The remaining 27% lags can be described to be redundant. The coefficients in the local linear estimator are 0.9476291 and 0.958792 respectively which compared to an OLS as given above are slightly smaller

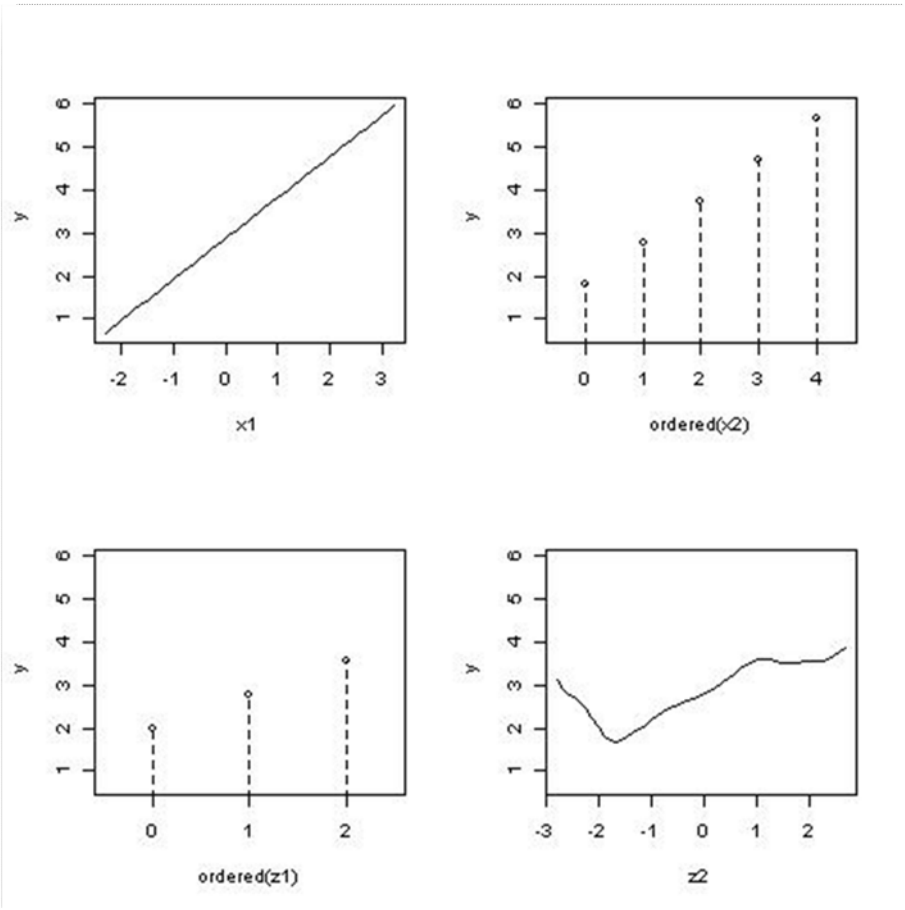


Figure 27: The plots of the OLS fitted and local linear polynomial

To plot regression surfaces with variability bounds constructed from bootstrapped standard errors, then the diagram below shows the uniform bands.

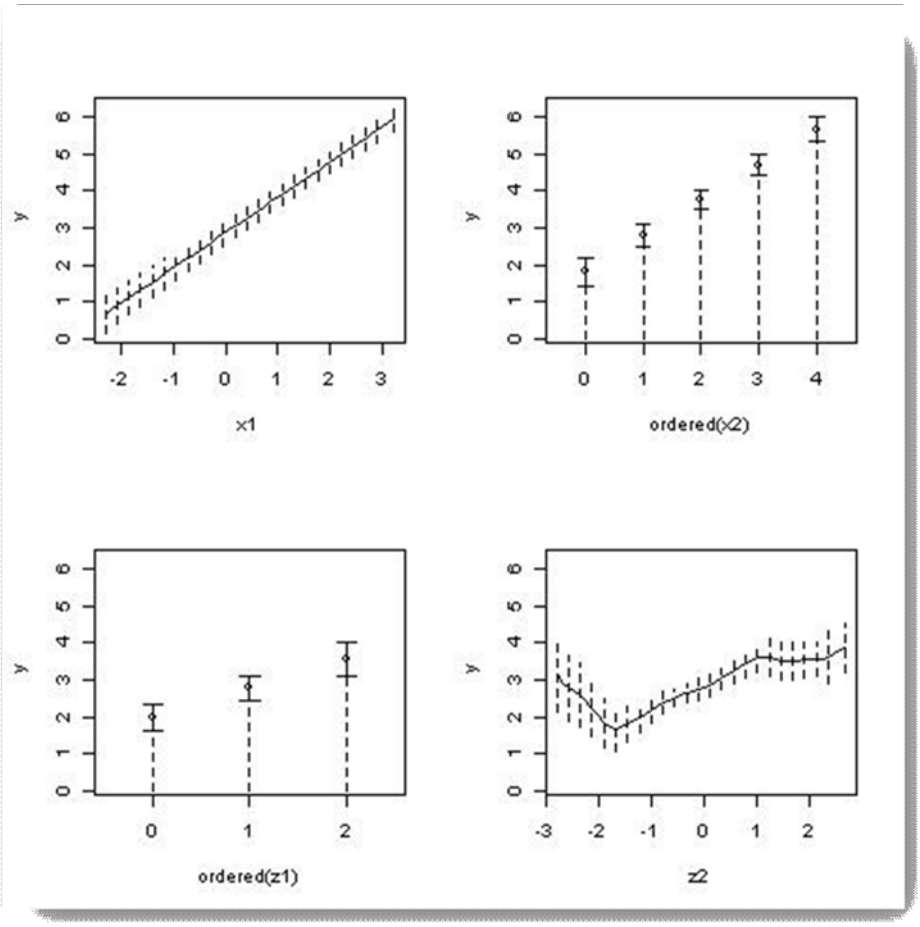


Figure 28: Bootstrapped estimators for both OLS and the local linear

7.0 Conclusions

In this paper we have shown that the local linear estimator out-performs the ordinary linear regression in mimicking the financial time series data generating mechanism. With an optimal bandwidth and lags, we are able to demonstrate that we can estimate the values of the quantile estimates for conditional mean and variance that are used to put a bound on the risk levels applied in financial risk management. Also we have demonstrated the bootstrap confidence for both estimators in both the ordered and the unordered sets will give a uniform bound on the expected extends of the values of the estimates

References

Ait-Sahalia, Y. (1996). Testing continuous-time models of the spot interest rate. *Review of Financial Studies **9***, pp 385-426.

Baillie, R. T. and Bollerslev, T. (1992). Prediction in dynamics models with time dependent conditional variances. *Journal of Econometrics,* **52** , pp 91-113.

Black, F. and Scholes, M. (1973). The pricing of options and corporate liabilities, 71. *Journal of Poolitical Economy*, pp 637-653.

Claeskens, G. van Keilegom, I. (2003). Bootstrap confidence bands for regression curves and their derivatives. *Annals of Statistics,* **31**(6), pp 1852-1884.

Fama, E. (1970). Efficient Capital markets: A review of theory and empirical work. *Journal of Finance,* **25**, pp 383-417.

Fan, J. and Gijbels, I. (1996). Local Polynomial Modelling and Its Applications. London. Chapman and Hall.

Gospodinov, N. (2002). Median unbiased forecasts for highly persistent autogressive process. *Journal of Econometric*.

Hardle, W. (1990). Applied Nonparametric Regression. New York: Cambridge University Press.

Hardle, W. and Bowman, A. W. (1988). Bootstrapping in nonparametric regression: Local adaptive smoothing and confidence bands. *Journal of American Statistical Assiociation,* **83**(401*)*, PP 102-110.

Hardle, W. and Marron, J. S.. (1991). Bootstrap simultaneous error bars for nonparametric regression. *Annals of Statistics,* **19**(2), pp 778-796.

Kim, J. H. (2001). Boostrap-after-boostrap prediction intervals for autoregressive models. *Journal of Business & Economics,* **19**, pp 117-128.

Li, Q. and Racine, J. (2007). Nonparametric Econometrics: Theory and Applications*,*. Princeton University Press.

Mandelbrot, B. (1963). The variation of certain speculative prices. *J.,Bus* , pp 394–419.

McMurry, T. and Politis, D. N. (2004). Nonparametric regression with infinite order flat-top kernels. *Journal of Nonparametric Statistics,* **16**(3-4) , pp 549-562.

Merton, R. C. (1973). Theory of rational option pricing. *Bell Journal of Economics and Management Science,* **4**, pp 141-183.

Miguel, J. A. and Olave, P. (1999). Forecast intervals in ARCH models: Boostrap verses parametric methods,. *Applied Economics Letters,* **6**, pp 323-27.

Neumann, M. H. Polzehl, J. (1998). Simulataneous bootstrap confidence bands in nonparametric regression. *Journal of Nonparametric Statistics,* **9**, pp 307-333.

Pagan, A. R. and Ullah, A. (1999). Nonparametric Econometrics,. New York: Cambridge University Press.

Pascual, L., Romo, J. and Ruiz, E. (2000). Forecasting returns and volatilities in GARCH processes using boostrap. Working paper 00-68(31), Universidad.

Pascual, L., Romo, J. and Ruiz, E. (1998). Boostrap predictive inference for ARIMA processes. *Universidad Carlos III de Madrid, Spain* , Working paper 98-86.

Stanton, R. (1997). A nonparametric model of term structure dynamics and the market price of interest rate risk. *Journal of Finance* **52**, pp 1973-2002.

Taylor, S. (2005). Asset Price Dynamics, Volatility, And Prediction. Princeton, NJ.: Princeton University Press.

Tsay, R S. (2005). Analysis of Financial Time Series, 2th Edition. New York.: John Wiley and Sons.

Wang, and Wahba, G. (1995). Bootstrap confidence intervals for smoothing splines and their comparison to bayesian confidence intervals. *Journal of Statistical Computation and Simulation,* **50**, pp 263-279.

MONITORING OF RADIOFREQUENCY RADIATION FROM SELECTED MOBILE TELEPHONES IN KENYA

W. Ombati[1], R. Kinyua[2], J. Mutuku[3] and C. Ogongo[2]
[1,2,3]Department of Physics, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[2]Communications Commission of Kenya, Nairobi, Kenya
E-mail: wilombati@gmail.com

Abstract
The intensity of radiation around various GSM phone models has been measured using broadband radiofrequency meter and spectrum analyzer and the results assessed based upon the established international safety standards on non-ionizing radiation. The results obtained in this study have shown the presence of radiation levels from all the selected mobile phone models, ranging from 0.01134 to 0.4671 $mWcm^{-2}$ with the highest from Nokia Series (China) N95 and lowest from Nokia 1110. These radiation levels are within the recommended exposure limits. It has further been established that high radiation intensities from a transmitting handset appear between the dial and reception of a call. The use of different anti-radiation filters in abating mobile phone radiation has also been found effective, but with different degrees of efficiencies of which none meets the 99% efficiency asserted by the respective manufacturers. It has also been established that the radiation levels from a mobile phone are affected by the physical condition of the body. The International Mobile Equipment Identifiers (IMEIs) of the handsets under-study were also assessed for compliance to established standards.

Key words: Broadband RF meter, mobile phone, radiation, radiofrequency (RF), safety standards

1.0 Introduction

The mobile communication industry in Kenya is experiencing rapid growth. This is a direct consequence of a high rate at which cellular technologies are transcending the world and consequent increase in economic activities. The significant introduction of new products such as *m*-Pesa, Zap, yuCash and *m*-Kesho, reduction in the costs of mobile phone handsets, reduction in call charges and the growth of mobile penetration in Kenya have also fueled the expansion of this industry. Currently, there are about 19.4 million mobile phone subscribers in Kenya (CCK, 2010) and this is expected to rise to 29.28 million, or 66.7% penetration, by the year 2013 (ATMR, 2009; ITU, 2009). To support the growing demand of mobile services, the Communications Commission of Kenya has, at the moment, licensed four mobile operators: Safaricom, Zain, Orange and YU under the category of the Network Facility Provider (NFP) in a unified licensing framework, commanding 80.25%, 12.11%, 4.27% and 3.37% subscriber-base respectively (CCK, 2010; AWC, 2010). These operators use Global System for Mobile communication (GSM) or 2G-technology, and are advancing towards adapting the 3G-technology.

Mobile phones transmit and receive signals, via a base station system, using radio waves. Currently, there are about 4000 base stations in Kenya (RPB, 2008). And with the increasing use of mobile phones, more installation of base stations are expected; this would as well increase radiofrequency (RF) radiation in our environment. Exposure to RF radiation (RFR) is categorized into two: occupational and general-public exposure (ICNIRP, 1998). In occupational exposure, persons exposed as a consequence of their employment are fully aware of the danger of such exposure and take necessary precautionary measures. Otherwise, exposure that is not employment-related such as mobile phone radiation is classified under general-public exposure. Various organizations such as the U.S. Federal Communications Commission (FCC) and International Commission of Non-Ionizing Radiation Protection (ICNIRP) have set RF exposure limits, as shown in Table 1.

Table 1: Levels of occupational and general-public exposure (Barnes1999)

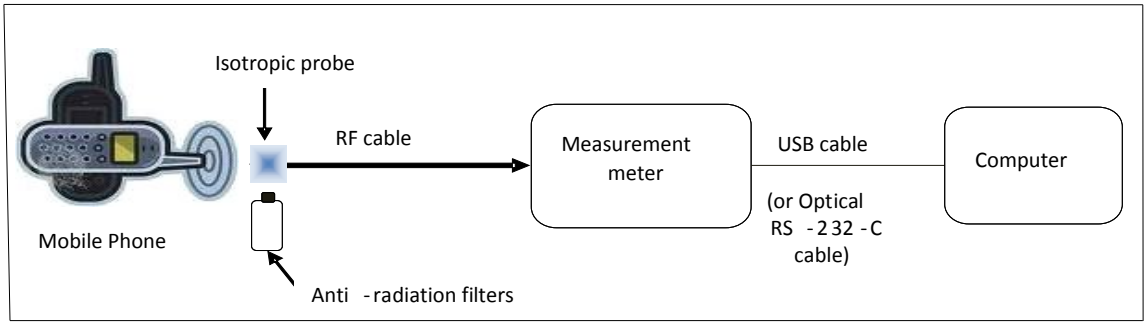
Standard	Intensity at 900 MHz ($mWcm^{-2}$)		Intensity at 1800 MHz ($mWcm^{-2}$)	
	Occupational	General Public	Occupational	General Public
ICNIRP	2.418	0.451	4.297	0.902
NCRP/FCC	3.0	0.6	5.0	1.0
1992 ANSI/IEEE	3.0	0.6	6.0	1.2

Exposure to RFR above the reference limits is termed as hazardous. Accruing health effects due to such exposures are thermally and non-thermally induced. Absorption of RF energy by biological tissues and the heating thereof is facilitated by electrical properties of bio-matter and the body's thermoregulatory mechanism (Hyland, 2000). The amount of heat produced in the exposed tissues depends primarily on exposure time and the intensity of radiation penetrating the system. The World Health Organization (WHO, 2000) has connected brain cancer with RF exposures, and Maneesh *et al.* (2009) have determined that the most thermally vulnerable organs include genitals and eyes. Other effects include a stinging sensation and a feeling of heat in the facial skin (Sandström *et al.*, 1998). Non-thermal effects such as headache, dizziness, fatigue, stress, difficulties in concentrating and nausea have been reported by Krewski *et al.,* (2007), Anita (2005) and Frey (1998). In this work, the intensities of RFR from selected mobile phones in Kenya are investigated under different exposure conditions and then assessed based on the established safety standards on non-ionizing radiation.

2.0 Materials and Methods

The GSM handsets under study are Nokia-1100, 1110, 1200, 1202, 2626, 1661, 6300; Nokia Series (China) N95; Smadl-A30, A56; Tecno-T570, T780; TV22i; iPhone- i9+; Long Ke- S350; TOP-1 006; J-Max: Double-Life; Samsung- GT-E1080T; Blackberry-7290 and Motorolla C118. These handsets were fully charged so as to avoid the risk of switching off during the measurement process.

The intensity of RF energy radiated from each handset was measured by broadband RF meter (NBM-550) connected with E-field isotropic probe (EF1891). In monitoring the signal strength and frequency specific to GSM band (900 MHz), a spectrum analyzer (FSH18) was connected with broadband active directional antenna (HE300). The frequency range of the E-field probe is 3 MHz to18 GHz and electrical field strength of 1.0 – 600 mVm^{-1}. This probe was used to detect and measure (in XYZ planes) the RF signal from a transmitting handset, and would perform vector addition of individual readings and send the results on the display provided by the broadband RF meter. Radiation levels at close proximity to the transmitting handset, at the ear piece, were first determined and referred to as normal radiation level *N*.
Radiation levels at the back (around the battery compartment) of the activated handset, with and without battery/ rear-body cover, were also measured and compared with respective *Ns*. The intensity of radiation from each of the selected handsets was also suppressed using three anti-radiation filters from different manufacturers and their effectiveness assessed and compared. The radiation measurement set-up is shown in Figure 1.



-up

Figure 1: Radiation measurement set

The measurement meter consisted of the broadband RF meter and spectrum analyzer connected to the computer via USB and RS-232-C optical interface respectively. The broadband RF meter measures the cumulative radiation, contribution of background and mobile phone radiation. To obtain the actual radiation level for each handset, respective average background radiation was off-set from the measured value. Radiation measurements for each phone were taken six times at intervals of one minute each and an average value was calculated. The process was then repeated thrice to determine the consistency of the results.

3.0 Results and Discussion

3.1 Background Radiation

In this study, measurement of background radiation (BGR) was carried out so as to determine the baseline exposure of the general public to electromagnetic radiation within the measurement vicinity. It further enabled the monitoring and isolation of the BGR levels (in the measurement room) from the mobile phone radiation level(s). Figure 2 shows a graphical representation of average BGR levels with time of the day.

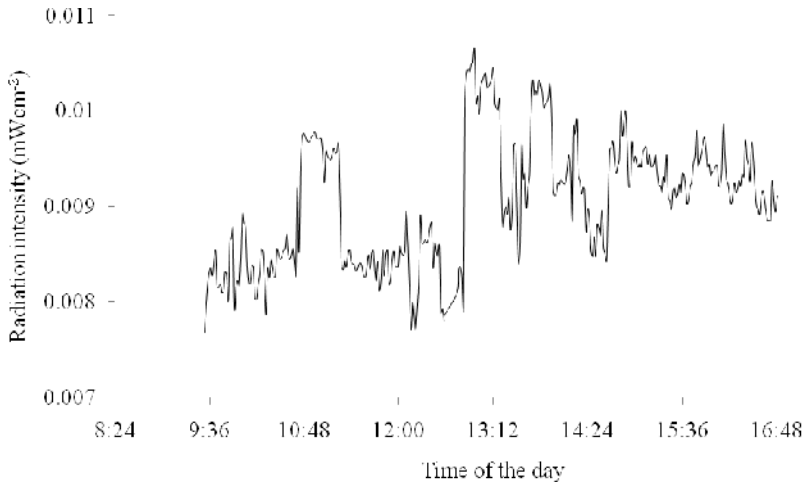


Figure 2: Variation of average background radiation with time

The results showed that the intensity of BGR ranged from 0.007681(1.7% of ICNIRP reference level) to 0.010643 $mWcm^{-2}$ (2.4% of ICNIRP reference level). Minimum and maximum peak intensities were observed at 9.32 am and 12.57 p.m., respectively. The average BGR level is 0.009048 $mWcm^{-2}$ (2.0% of ICNIRP reference level), with 4.3735×10^{-7} variance index.

In Figure 2, it is also evidently clear that the BGR in the morning and afternoon greatly contrasts. Average BGR before noon is 0.00861 $mWcm^{-2}$ (1.9% of ICNIRP reference level) whereas in the afternoon, it is 0.00925 $mWcm^{-2}$ (2.1% of ICNIRP reference level). The low BGR levels witnessed in the morning hours are as a result of little mobile-communications owing to a hub of office activities and may also be attributed to low solar activity. Notable increment of BGR is also however observed between 10.30am to 11.15am; this can be attributed to increased communications by staff during the tea break session. Maximum peak radiation levels were observed at lunch break, between 12.56pm and 2.15pm. During this period, the traffic in the GSM network is usually high; hence the increase in radiation in the measurement vicinity.

3.2 Electromagnetic Radiation Levels from Mobile Phone Handsets

The intensity of radiation from various mobile stations when establishing a call and during conversation was measured and observed to vary as shown in Figure 3. The high power(s) witnessed when dialing the GSM network is needed by the mobile station in reaching and picking a signal from the base transceiver station (BTS). The apparent drop in power during conversion is attributed to adaptive power control (APC) and discontinuous transmission (DTX). APC minimizes transmitter power of the handset and reduces multiple-access interference effect in order for the BTS to receive the usable signal. DTX turns off transmission during pauses within speech; so, the user is exposed to the radiation arising from the conversation a part of the time only. The said phenomenon is witnessed whenever a transmitting handset is placed next to a speaker; the cracking noise (adverse electromagnetic interference effects) in the speaker which degenerates with time after connection acknowledgement.

From the obtained results, it is apparent that mobile phone users who take long before “answering” a call are likely to be exposed to higher radiation levels. The accruing health effects may include heating and tingling of the exposed tissues especially the ear and thighs, headache and psychological disorders as reported by Barnes (1999) and Krewski *et al.* (2007).

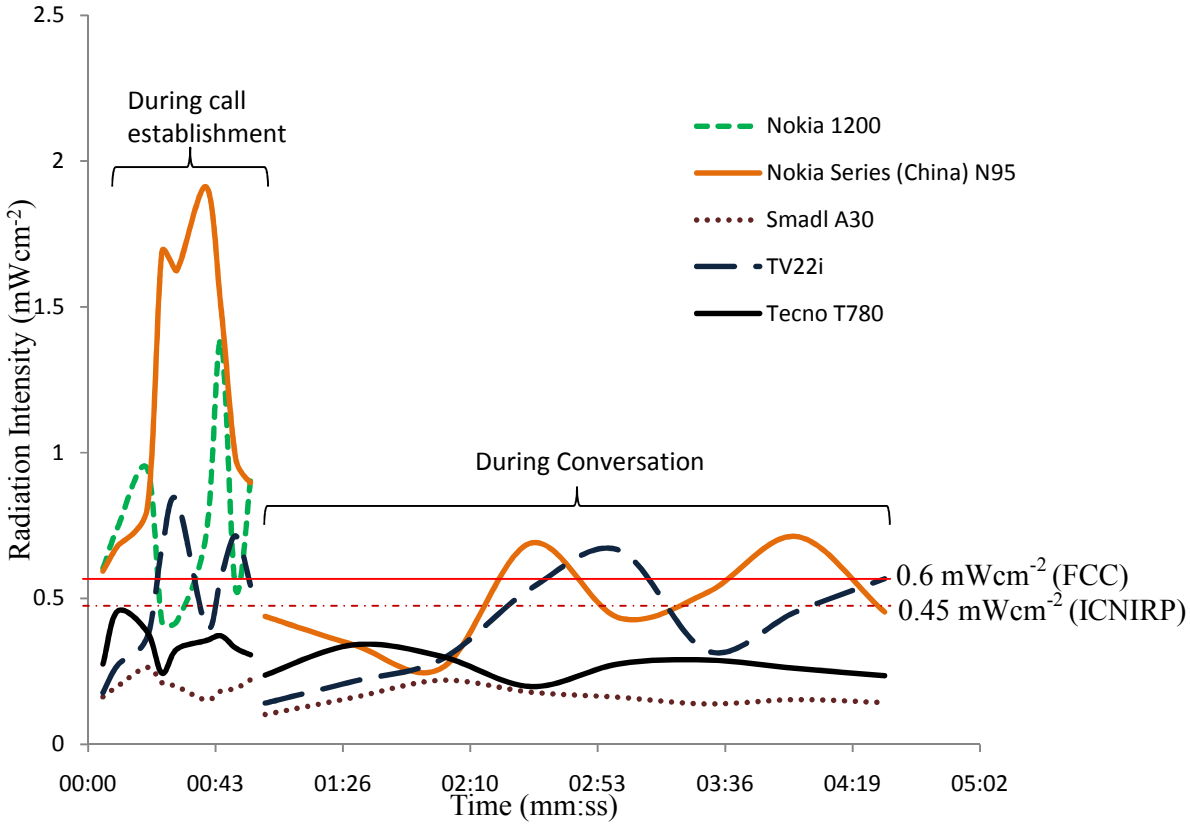


Figure 3: Variation of radiation intensity with time- during call establishment and conversation

A comparative study of average intensities among different activated mobile phones, during conversation, is presented in Figure 4. The mean intensity from each of the handsets under study had the BGR subtracted and was shown to vary with handset model. The highest and least radiating handset was, respectively, Nokia Series (China) N95 (0.467 $mWcm^{-2}$, 104% of ICNIRP reference level) and Nokia 1110 (0.0113 $mWcm^{-2}$, 25% of ICNIRP reference level). The intensities of all the tested handsets, except N95, were below ICNIRP's recommended limit; however, the limit of N95 is within FCC reference level.

In this work, the intensity of radiation from N1100 was 0.1537 $mWcm^{-2}$; which is comparably smaller than 0.45 $mWcm^{-2}$ reported by Usikalu and Akinyemi (2007). Such variation would be a consequence of change of the manufacturing technologies and different RF detection capabilities of measuring equipment used in these studies.

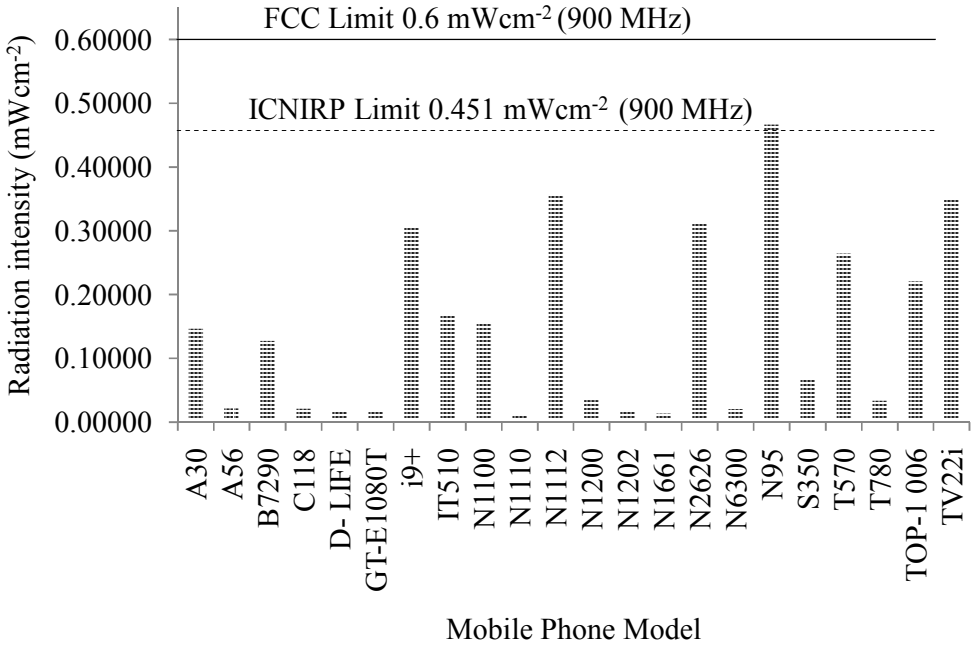


Figure 4: Intensity of radiation measured at the ear-piece among different handset models during the conversation mode

In determining the intensity of sampled handsets, the base signal strength was constantly monitored. The signal strength within the measurement room was always determined to be stable. However, according to Stewart (2000), if the measurement is carried out in poor network environment, the power density would increase since a lot of power would be required in order to hook-up the mobile station with the BTS. Furthermore, Usikalu and Akinyemi (2007) have shown that if calls are made while charging the batteries of mobile phones, extremely low frequency radiation would also enhance the measured radiation. Some properties such as Bluetooth services could also increase RF emissions (Damir *et al., 2004*). In this regard therefore, the use of N95 under such conditions would possibly be unsafe.

3.3 Effectiveness of Anti-Radiation Filters

The use of anti-radiation filters in suppressing RFR from different selected mobile phone models was investigated. In Figure 5, it has clearly been demonstrated that the use of anti-radiation filters led to a significant reduction of radiation levels. Radiation reduction efficiency is also shown to vary with the type of anti-radiation filter.

The results have explicitly shown that incident RFR is suppressed at different rates. Of the three filters used, “EM Wave Protection Sticker” from LG (Korea) was the most effective (44.8%); “Wave Scrambler” (China) was 23.2% and “Safe Guard” (Japan) was 34.8% effective. All manufacturers of such products guarantee consumers 99% radiation reduction efficiency. However, it is evidently clear that none of them meets this claim.

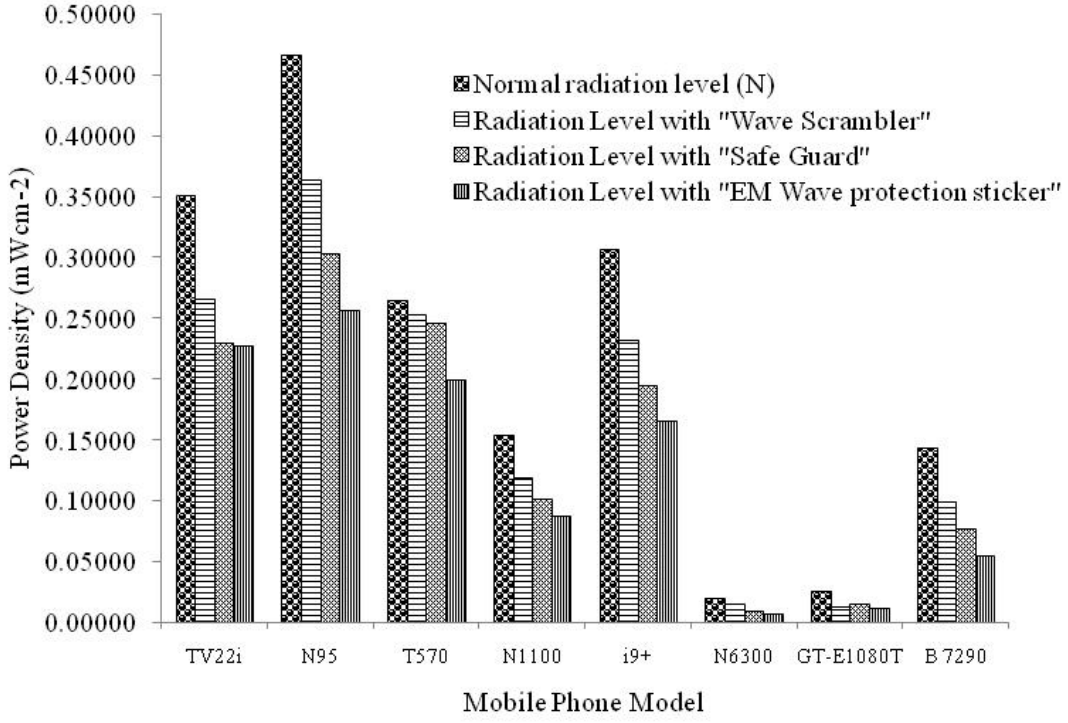


Figure 5: Radiation levels from different activated handset models with anti-radiation filters

Based upon the obtained results, the variation in efficiency can clearly be attributed to the quality and material composition of the anti-radiation filter. The "Wave Scrambler" is made of special ceramics and copper, "Safe Guard" is made of fine strands of polyester coated with copper, nickel and carbon whereas "EM Wave Protection Sticker" is made of epoxy resin and lead. These materials have different thermal conductivities and dielectric constants as reported by Yoshihiro and Takahashi (2008), who have also shown that the type, amount and size of metamaterials determine the effectiveness of such devices in suppressing mobile-phone radiation. In the present study, the effect of surface area of these anti-radiation filters on radiation reduction efficiencies is observed. Of the three filters, the surface area of "EM Wave Protection Sticker" was the largest. This implies that the EM waves were exposed over a large area, and thus neutralization and EMR shielding effectiveness was high.

3.4 Effect of Handset's Physical Condition on Mobile Phone Radiation

Unlike RF radiation from base stations, radiation from mobile phones is non-directional; that is it spreads over and around the user. Any opening, such as earpiece and battery cover, serves as exiting points for such a radiation. In this study, the effect of handset's physical condition on radiation exposure levels has been examined by considering the state or nature of its casing and naked-state. Respective mobile phone radiation levels around the earpiece region, normal radiation level (*N*), are compared with radiation levels around the battery compartment area: with and without the battery cover.

In Figure 6, the intensity of radiation around a battery compartment of transmitting (battery) uncovered handset was observed to be comparably higher than a transmitting battery-covered handset. The battery cover served as an attenuating medium; therefore in its absence, the air acted as an attenuator. The radiation levels for TV22i, S350 and i9+ were lower than their respective normal radiation levels (*N*s); only Blackberry 7290, Smadl A30 and Nokia 1202 had slightly higher intensities than their respective *N*s. The battery covers of S350, TV22i and i9+ were metallic but the

casing of Blackberry 7290, Nokia 1202 and Smadl A30 were plastic in nature; This accounts for their difference in attenuating capabilities with metals attenuating more than plastic casing.

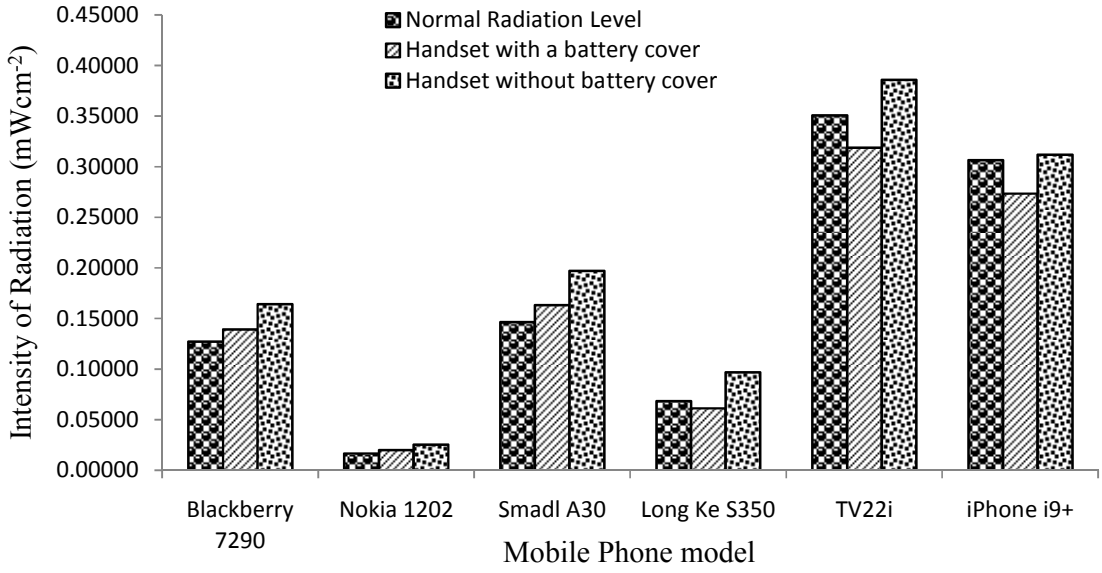


Figure 6: Radiation levels from selected handset models with/without battery cover

Possible Implications: This study has demonstrated that the use of an activated mobile phone with uncovered battery compartment would increase the user's exposure to RF radiation. Though none of tested phones emitted radiation levels above recommended limits, the battery-covered handsets would be much safer to use. Although a mobile phone can operate normally even in the absence of the battery-cover or even the rear body-cover, its effect on the emitted radiation cannot be ruled out. The loss of either part of the mobile phone, irrespective of its working condition, should therefore be replaced.

3.5 Assessment of Mobile Phones Compliance to IMEI Standards

The international mobile equipment identifiers (IMEIs) of the tested mobile phones were checked based on two methods: reading the IMEI on the compliance plate (white paper in the battery compartment) and IMEI displayed by the handset's software (by dialing *#06#). Both methods ought to give the same IMEI per mobile phone under-study. Each IMEI was then analyzed on two accounts: Luhn Check-digit computation and International Number Plans (INP) scheme. The full spectrum of the IMEI results is presented in Table 2.

Table 2: IMEI results and analysis

Mobile equipment (ME)	*IMEI*		*Origin*	*IME evaluation (INP)*	
	Code displayed on screen (#06*)*	*Code read on the compliance plate*		*Type allocation holder*	*Mobile Equipment Type*
Nokia 2626	353942017756715	353942017756715	Hungary	NOKIA	NOKIA 2626
Blackberry 7290	357779000735454	357779000735454	Canada	Blackberry	Blackberry 7290
Tecno T780	354609020997706	354609020997706	China	TECNO	TECNO T780
Nokia 1661	355205031721638	355205031721638	India	NOKIA	NOKIA 1661/1662
Nokia 1100	357264013079151	357264013079151	Hungary	-	-
Nokia 6300	352943015160042	352943015160042	Hungary	-	-
Samsung GT-E1080T	357064038877945	357064038877945	Philippines	-	-
Smadl A56	354726030217642	354726030217642	China	-	-
J-Max Double Life	350077215552989	350077215552989	China	Siemens	Siemens S40
Smadl A30	353304000128305	353304000128305	China	Hitachi	Hitachi HTG-989
Nokia 1200	**350622020218092**	353265016021331	Hungary	**Kejian**; Nokia	**Kejian K7100**; Nokia 1600
iTEL IT510	135790246811220	353261030056783	China	-	-
Long Ke S350	354756500713920	354756500713919	China	-	-
Nokia 1202	357622024778177	355005360081046	Hungary	-	-
Tecno T570	357170023202005	357170023202005	China	-	-
	000000000000000			-	Test phone
Simba FV100	356688000028730	356688000028730	China	Amoi	Amoi M350
	000000000000000			-	Test phone
Nokia Series N95	357087084598438	357087084598438	China	-	-
	357087084598446			-	-
	357087083837787			-	-
iPhone i9+	354236021053491	355200903192324	China	-	-
	356893066053491			-	-
TOP-1 006	357357030179017	357357030179017	China	-	-
	357357030279015			-	-
Zetel N85y	352154000546902	352154000546902	China	TCL Mobile	TCL GA16 / TCL E757
	352154001546901			TCL Mobile	TCL GA16 / TCL E757
G-Tide (G19)	359005034010385	359005034010385	China	G-Tide	G-Tide M8 / G19 / G28
	359005034029880			G-Tide	G-Tide M8 / G19 / G28

From the obtained results, the mobile phones whose IMEIs on the screen coincided with the code on the compliance plate include: Nokia 2626, 1100, 1661 and 6300, Tecno T780, Samsung- GT-E1080T, J-Max Double-life and Blackberry 7290. Of all these IMEIs, only Blackberry 7290, Tecno T780, Nokia 2626 and 1661 perfectly matched with type allocation holder (manufacturer) as well as mobile equipment type in the INP database.

The mobile phones whose type allocation holder(s) and equipment type(s) were not available in the INP database include: Nokia 1100, Nokia 6300, Smadl A56, Samsung GT-E1080T, iTel IT510, Long Ke S350, Nokia 102, Tecno T570, N95, iPhone i9+ and TOP-1 006. Mobile phones whose IMEIs were accredited to different manufacturers and model types were Smadl A30 (Hitachi, HTG-989), J-Max Double-life (Siemens, S40), Nokia 1200 (Kejian, K7100; Nokia, N1600), Simba FV100 (Amoi, M350) and Zetel N85y (TCL Mobile, E757).

Some phones such as Nokia 1200 and 1202, iTel IT510 and Long Ke S350 displayed only one IMEI on the screen but a different code on the compliance plate. The IMEI displayed on the screen of IT510 was invalid; it would not be identified with any Reporting Body Identifier nor did it comply with Luhn Check-digit computation and specific information regarding this phone was missing in INP database.

Mobile phones with more than one IMEI codes displayed on the screen include: G-Tide G19, Zetel N85y, TOP1-006, iPhone i9+, Nokia Series N95, Simba FV100 and Tecno T570. One of these IMEIs coincided with the one on the compliance plate of the corresponding and respective mobile phone. One IMEI of FV100 and T570 was 000000000000000, an IMEI allocated only to test mobile phones.

4.0 Conclusion

Electromagnetic radiation levels varied with mobile phone models. The radiation levels ranged from 0.113 to 0.467 $mWcm^{-2}$ with the highest radiating mobile phone being Nokia Series (China) N95 while the least was Nokia 1110. All the radiation levels of the 22 handsets were within the safe exposure limits.

The radiation intensities from a transmitting handset are high while dialing the network. Such radiation levels have been found to vary with handset model and decrease during conversation.
The use of anti-radiation filters in abating RF radiation has been found effective. Amongst the three anti-radiation filters used, “EM Wave Protection Sticker” from LG (Korea) was the most effective (44.4%). The efficiencies of “Sage guard” and “Wave Scrambler” were 34.8% and 23.2% respectively. However, none of the filters was 99% effective as asserted by respective manufacturers.

Radiation levels from a handset were affected by its physical condition. Radiation intensity accruing from the use of a naked handset, for instance, was found to be higher than the normal radiation level as well as the intensity from a cased handset. Handset with metallic casing such as TV22i was found to attenuate much radiation than plastic-cased handsets such as Nokia 1202.
Most of the branded handsets under test were not compliant to the IMEI standards. Only, Blackberry 7290, Tecno T780, Nokia 2626 and 1661were adhered to such regulations; This constitutes of 20% of the assessed mobile phones.

References

Anita, G. G. (2005). Genetic damage in mobile phone users: some preliminary findings. *Indian Journal of Medical Genetics , **11*** (2), pp 99-103.

ATMR. (2009). *Africa Telecom Market Report:2008-2009.* Research and Markets Ltd. Dublin 8, Ireland.

AWC (2010). (African Wireless Communications Yearbook). Kadium Publishing (Pty) Ltd. 41

Barnes, H. J. (1999). Cell Phones: Are they Safe? American Society of Safety Engineers, December Edition, 21.

CCK **(**2010**).** Quaterly Sector Statistics Report*:* 2nd Quarter, Oct-Dec 2009/2010. Communications Commission of Kenya, Nairobi 4.

Damir, K., KreSimir, M. and Tomislav, M. (2004). Measurement of mobile phone radiations in respect to human exposure standards. 46th International Symposium on Electronics in Marine, ELMAR-PW4, (pp. 515-519). Zadar, Croatia: IEEE Xplore.

Frey, A. (1998). Headaches from cellular telephones: Are they real and what are the implications? *Environmental Health Perspective,* **106**, pp 101-103.

Hyland, G. J. (2000). Physics and biology of mobile telephony. *Lancet ,* **356**, pp 1833-1836.

ICNIRP (1998). Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300GHz). *Health Physics Society,* **74**(4), pp 494-522.

INP (International Numbering Plans) (2010). *Number analysis tools.* Accessed on 23rd May, 2010 from: http://www.numberingplans.com.

ITU. (2009). ITU Report for 2009: Kenya Poised for Huge Growth in Mobile Services. International Telecommunications Union.

KIA. (2000). Information and Communication Technology. *Monthly Review (January Edition)*. Kenya Investment Authority Ltd. Nairobi, Kenya.

Krewski, D., Barry, W. G., Riadh, W. Y., Brian, H., Lotz, W. G. and Rosemonde, M. (2007). Recent advances in research on radiofrequency fields and health: 2001-2003. *Journal of Toxicology and Environmental Health,* **10**, pp 287–318.

Maneesh, M., Anil, P. K., Jayalekshmi, H., Bhargav, K., and Rohith, V. (2009). Radio frequency electromagnetic radiation (RF-EMR) from GSM (0.9/1.8GHz) mobile phones induces oxidative stress and reduces sperm motility in rats. *Clinical Science ,* **64**(6), pp 561-565.

RPB. (2008). Export/Import control procedures. Radiation Protection Board of Kenya. Nairobi, Kenya.

Sandström, M., Mild, K. H., Wilén, J. and Oftedal, G. (1998). Symptoms associated with mobile phone use: Results of the Swedish-Norwegian Survey. *Occupational Medicine,* **48**, pp 357-360.

WHO. (2000). Electromagnetic fields and public health:mobile telephones and their base stations. *Fact sheet No. 193* . World Health Organization. Geneva, Swizerland.

Yoshihiro, S., and Takahashi, S. (2008). Material design of functionally graded plates with the function of electromagnetic noise suppression (Quantitative evaluation of the effect of electromagnetic noise suppression). *Journal of Solid Mechanics and Material Engineering,* **2**(7), pp 912-920.

DESIGN AND IMPLEMENTATION OF AN OBJECT ORIENTED PROGRAMING LANGUAGE

R. Mokua[1], W. Mwangi[2], J. M. Kanyaru[3]
[1,2]Institute of Computer Science and Information Technology, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[3]Software Systems Research Center, Bournemouth University, United Kingdom
E-mail: mokua.richard@gmail.com

Abstract
This paper presents work done to address two issues of interest to both Programming Language (PL) theory and software development: 1) The inadequacies of mainstream Object Oriented Programming Languages used in the software industry such as Java, C# and C++ and 2) The design and implementation of a statically typed Object Oriented Programming Language that addresses some of the issues identified above. Research was conducted through critical analysis of existing Object Oriented Programming Languages (OOPL) as well as a literature review of journal and conference publications in that area. The aim was to elicit evidence of PL constructs that had been found through previous experience to lead to poor Software Engineering practices such as increased amount of bugs, poor maintainability, late (i.e. runtime) detection of errors, poor usability and low programmer productivity. This work has produced key benefits that include a deeper understanding of PLs specifically OOPLs, and an improved comprehension and appreciation of the nuances of PL design. The findings have the potential to benefit PL researchers and designers in various ways. The contributions of this work are that a list of the language constructs (e.g., Static Variables, Lack of Object Level Encapsulation, Presence of Primitive Types) that seem to lead to poor Software Engineering practices with current OOPL have been identified. A further significant contribution is the production of a new OOPL designed to act as proof of concept to illustrate how these issues can be addressed.

Key words: Object oriented programming language, compilers, software engineering, type systems, compiler design and construction

1.0 Introduction

Most programming languages can be classified into families based on their model of computation (Scott,2000). Declarative languages focus on instructing the computer *what* to do while imperative languages focuses on *how* the computer should do it.

Declarative languages can further be divided into the following sub-categories:
Functional languages employ a computational model based on the recursive definition of functions. They take their inspiration from the lambda calculus (Barendregt, 1981). In essence, a program is considered a function from inputs to outputs, defined in terms of simpler functions through a process of refinement. Languages in this category include Lisp (Harrison, 1967), ML (Milner et al, 1990) and Haskell (O'Sullivan et al, 2008).

Dataflow languages model computation as the flow of information (tokens) among primitive functional nodes. Val (Ackerman and Jack, 1979) is an example of a language from this category.

Logic or *constraint-based languages* take their inspiration from predicate logic. They model computation as an attempt to find values that satisfy certain specified relationships, using a goal-directed search through a list of logical rules. Prolog (Clocksin and Mellish, 1981) is the best-known logic language.

Imperative languages are divided into the following subcategories:
von Neumann languages are the most familiar and commonly used programming languages. They include FORTRAN (Chivers and Sleighthome, 2005), Ada 83 (Barnes, 2008), C (Kernighan and Dennis, 1978), and all of the others in which the basic means of computation is the modification of variables (Scott,2000).

Object-oriented languages are comparatively recent, though their roots can be traced to Simula 67(Dahl et al, 1968) .Most are closely related to the von Neumann languages but have a much more structured and distributed model of both memory and computation. Rather than picture computation as the operation of a monolithic processor on a monolithic memory, object-oriented languages picture it as interactions among semi-independent objects, each of which has both its own internal state and subroutines to manage that state. Smalltalk (Goldberg, A, and David R , 1985) is the purest of the object-oriented languages; C++ (Stroustrup , 1997) and Java (Gosling et al , 2005) are the most widely used.

Programming Languages can also be categorized based on if they have a type system or not. In *typed languages*, program variables have an upper bound on the range of values that they can assume. On the other hand, *un-typed languages* do not restrict the range of variables (Cardelli, 1996).

In Typed languages, the compiler can enforce good behavior by performing static (i.e., compile time) checks to prevent unsafe and ill behaved programs from ever running. These languages are said to be statically checked (Cardelli, 1996).On the other hand, the type checking may be delayed until runtime, in which case the language is said to be dynamically typed (Cardelli, 1996).

Examples of Object Oriented Languages that are statically typed include Java and C++ while those that are dynamically typed include Clojure (Halloway, 2009) and Smalltalk.

According to research done by the TIOBE Index , Object-oriented statically typed languages have been the most popular category of Programming Languages for more than 4 years now. Due to the fact that these are the most popular languages, it makes sense to invest time and energy in improving such languages so that we can improve the programmer's productivity.

2.0 Contributions

The ISO/IEC 9126-1:2001 Standard identifies a set of non-functional requirements which enhances the quality of the software program. Some of these requirements are:

(I) *Maintainability* - Effort required to locate and fix an error in a program.
(II) *Testability* - Effort required for testing the programs for their functionality.
(III) *Portability* - Effort required for running the program from one platform to other or to different hardware.
(IV) *Reusability* - Extent to which the program or its parts can be used as building blocks for other programs.
(V) *Interoperability* - Effort required to couple one system to another.
(VI) *Security* - The capability of the software product to protect information and data so that unauthorized persons or systems cannot read or modify them and authorized persons or systems are not denied access to them.
(VII) *Expandability* - The ease with which the software can be modified to add functionality.
(VIII) *Simplicity* - Degree to which a program is understandable without much difficulty.
(IX) *Integrity* - Degree to which a program can continue to perform despite some violation of the assumptions in its specification. This implies, for example, that the program will properly handle inputs out of range, or in different format or type than defined, without degrading its performance of functions not dependent on the non-standard inputs (Boehm *et al*., 2006).

It's important that a programming language be able to provide constructs that enable the programmer to develop systems that observe the above software engineering principals. Further, the language should make it difficult for the programmer to implement systems that violate the above principles as much as possible.

Historically, Statically Typed Object Oriented Programming Languages (STOOPL) have included some features that have been known to lead to software systems that violate the above software engineering principles.

The contributions of this paper are as follows:
Identify language constructs whose use in writing programs violate the Software Engineering principles of Testability, Reusability, Security and Expandability; In Section II, we give a detailed list describing the issues identified; demonstrate through case studies and literature review ways in which such constructs affect the design principles identified above. In Section III of the paper, we delve in details into several case studies illustrating the effect of some of the identified constructs in real life large open source software projects and then how the issues were addressed; design the syntax and semantics of a language that solves the identified issues. We then continue to give a detailed overview of both the syntax and semantics (Section IV) of the new language and develop a prototype compiler for the languages. In Section V, we give an overview of the design of the compiler and the challenges experienced and tradeoffs made in the design and implementation.

2.1 Critique of the State of the Art

This research was undertaken using two key methods; first is the analysis of programming language theory and second experimenting with open source programming languages. We were able to identify several language constructs in most modern widely used Programming Languages that if used in the development of a software system they could lead to violation of some of the software engineering principles specified in the ISO/IEC 9126-1:2001 Standard.

2.2 Presence of Static Variables

If a field is declared static, there exist exactly one incarnation of the field, no matter how many instances (possibly zero) of the class may eventually be created. A static field, sometimes called a class variable, is incarnated when the class is initialized (Gosling et al , 2005).In Java, static means

one per class, not one for each object no matter how many instance of a class might exist. This means that a static variable can be used without creating an instance of the class. Static variable present a number of challenges in the language:

2.3 Static variables increase cases of security vulnerabilities

This is due to two factors, there is no way to check whether the code that changes such variables has the appropriate permissions and any mutable static state can cause unintended interactions between supposedly independent subsystems.

The key idea is that static state represents an ambient capability to do things to a system that may be taken advantage of by unauthorized persons or systems. Static variables leads to systems that are not re-entrant, i.e., it's not possible to have several concurrent executions of the software in the same VM. In the paper (Odersky and Zenger , 2005), the authors describe the following disadvantages that they encountered due to use of static variables in the first version of the Scala (Odersky *et al*., 2008) compiler.

Since all references between classes were hard links, they could not treat compiler classes as components that can be combined with different other components. This, in effect, prevented piecewise extensions or adaptations of the compiler and since the compiler worked with mutable static data structures, it was not re-entrant, i.e. it was not possible to have several concurrent executions of the compiler in a single VM. This was a problem for using the Scala compiler in integrated development environment such as Eclipse.

2.4 Static Variables Complicate Memory Management

According to the Java Language Specification (Gosling et al , 2005) section 12.7, Class unloading is an optimization that helps reduce memory use. However, if a class or interface ***C*** was unloaded while its defining loader was potentially reachable, then might be reloaded. This reloading needs to be transparent. However, reloading may not be transparent (and hence the class cannot be unloaded) if the class has; static variables (whose state would be lost); static initializers (which may have side effects) and native methods (which may retain static state).

2.5 Static Variables Increase the Startup Time

They encourage excess initialization up front. The Java Virtual Machine Specification (Lindholm and Yellin, 1999) specifies that: The static initializers and class variable initializers are executed in textual order. They may not refer to class variables declared in the class whose declarations appear textually after the use, even though these class variables are in scope. This restriction is designed to catch, at compile time, most circular or otherwise malformed initializations. Not to mention the complexities that static initialization engenders: it can deadlock, applications can see uninitialized state, and its hard to compile efficiently (because there is need to test if things are initialized on every use).

Use of static variables can easily lead to concurrency problems e.g. deadlocks; static variables are bad for distribution. Static state needs to either be replicated and synced across all nodes of a distributed system, or kept on a central node accessible by all others, or some compromise between the former and the latter. This is all difficult, expensive and unreliable; static variables make it difficult to do testing of code. The reason is that states in static values may be kept between unit tests because the class or dll is not unloaded and reloaded between each unit test. This violates the principle that unit tests should be independent of each other, and can result in tests passing and failing depending on the order in which they are run and static variables encourages designs using global variables hence makes it harder to re-use code.

3.0 Lack of Object Level Encapsulation

Most mainstream Object Oriented languages use *class* based encapsulation. The idea is that privacy is *per class*, not *per object*. This makes it possible to violate data abstraction as shown below.

```
class C {
  private i :String ;
def public m1(v : C) : Unit= { v.i = "XXX"}
}
```

As the above code illustrates, class based encapsulation does not protect one object from another since one object is able to access (and modify) the **private** attributes of another object. An alternative to class-based encapsulation is object based encapsulation. Privacy is per object. A member **M** marked with **private** modifier can be accessed only from within the object in which it is defined. That is, a selection **p.M** is only legal if the prefix is **this** or **O.this**, for some class **O** enclosing the reference.

```
class C {
  private i : String ;
def public m1(v : C) : Unit= { v.i = "XXX"} //Error
  def public m2():Unit = { this.i = "YY";} //Ok
}
```

A member labeled private is visible only inside the object that contains the member definition4**.0 Method Lookup Strategy**

In general, the semantics of a method invocation that has no explicit target (receiver) are that method lookup begins by searching the inheritance hierarchy of *self* (*this*); if no method is found, then the lookup procedure is repeated recursively at the next enclosing lexical level. This notion is described in detail in the Java Language Specification (Gosling et al, 2005) in section 15.12 (Method Invocation Expressions). Situations like the following can arise:

```
class Sup { }
class Outer {
  int m(){ return 91}
  class Inner extends Sup {
int foo(){return m()}// case 1: new Outer.Inner().foo() = 91
  }
}
}
```

The expectation is that a call to **foo** will yield the result 91, because it returns the result of the call to **m**, which is defined in the enclosing scope (Bracha, 2010). Consider what happens if one now modifies the definition of Sup:

```
class Sup {
    int m(){ return 42}// case 2: new Outer.Inner().foo() = 42
}
```

The result of calling **foo** is now 42. This is undesirable; since the behavior of the subclass changes in a way that its designer cannot anticipate. The classic semantics whereby inherited members may obscure lexically visible ones are counterintuitive. Lexically visible definitions should be given priority over inherited ones, either implicitly via scope rules or by requiring references to inherited features to explicitly specify their intended receiver. Retain implicit receivers for both self sends and outer sends, but reverse the priority so as to favor sends to names with locally visible definitions.

Presence of Primitive Types 5.0

Most mainstream statically typed object oriented languages divide their types into two categories, primitive (built in) types e.g. int, char, long, double, float,short and reference types, e.g., Integer, String.

This dichotomy presents a number of problems:

Dichotomy of basic semantics

Features of the language carry different meaning depending on the type of entity being dealt with. For example the built in operator == means different things depending on whether the variable types are primitives or reference types (Gosling *et al.,* 2005) .

Primitives cannot be used where objects are expected. For example, in the Java Language the container Vector cannot be used to store variables of primitive types, since it's designed to store variables of reference type Object.

Primitive types advertise their representation to the world

As one example, consider type char. When Java was introduced, the Unicode standard (Rossum and Drake, 2010) required 16 bits. This later changed, as 16 bits were inadequate to describe the world's characters. In the meantime, Java had committed to a 16 bit character type. Now, if characters were objects, their representation would be encapsulated, and nobody would be very much affected by how many bits are needed.

Primitive types necessitate the existence of special code which leads to the undoing of polymorphism. This is due to the fact that we cannot send messages to variables of primitive type. For example the String class has a static method valueOf that produces a String representation of its argument. For reference arguments, the Objects toString method is invoked.

```
public static String valueOf(Object o){
        return o == null? null :o.toString();
}
```

But this breaks down for primitive types necessitating overloading the valueOf() method for each of the primitive type.

```
public static String valueOf(boolean o){
        return o ? true :false;
}
```

1) The inclusion of primitive types forces Java Reflection API to be inconsistent and essentially broken to accommodate them.

```
String s =" test";
s.getClass(); // this is ok
int i = 20;
i.getClass();// compile error
```

Existence of Null Pointers 6.0

In current imperative languages, references (or pointers) can hold a special value meaning reference to nothing. This value is called *null* in Java. The **null** type has one value, the **null** reference, represented by the literal **null** (Gosling et al, 2005).Dereferencing a null at runtime results to a runtime error (*NullPointerException*) causing the current thread to exit if the exception is not handled.

Disadvantages of Null Pointers include, makes Java programs unsafe because when it occurs at runtime it causes system to crash; exceptions due to dereferencing a null pointer are the most common type of error in Java programs (Hovemeyer and Spacco , 2006;Cielecki et al ,2006) and It's among the Top 10 web application security risks.

Improving Opportunities for Reuse 7.0

Inheritance is commonly regarded as one of the fundamental features of object-oriented programming (Taivalsaaril, 1996). Over the years, researchers have developed various inheritance

models (Borning and Ingalls ,1982; Keene, 1989 ; Meyer, 1997) and *mixin* inheritance (Schaffert et al,1986;Ancona et al, 2000; Bracha and Cook, 1990;Flatt and Felleisen, 1998;Mens and van Limberghen,1996).All of these models have their conceptual and practical shortcomings with respect to reusability (Scharli et al, 2003). Inheritance also has other problems such as implementation difficulties (Cardelli, 1997; Taivalsaari, 1996) and conflicts between inheritance and *sub-typing*.

Single Inheritance - A class can inherit from at most one *superclass*. It is not expressive enough to allow the programmer to factor out all the common features shared by classes in a complex hierarchy. Hence single inheritance sometimes forces code duplication (Scharli et al, 2003).

Multiple Inheritance - enables a class to inherit features from more than one parent class, thus providing the benefits of better code reuse and more flexible modeling. However, multiple inheritance uses the notion of a class in two competing roles: the generator of instances and the unit of code reuse. This gives rise to the following difficulties (Scharli *et al.*, 2003), conflicting features; accessing overridden features and factoring out generic wrappers.

*Mixin Inheritance,*Total ordering,dispersal of glue code; ragile hierarchies.

Traits (Scharli *et al*., 2003; Scharli *et al*., 2002) improve code-sharing in Smalltalk by providing a means to reuse such behavior. Traits are a mechanism for code reuse that complements single inheritance. Traits, like classes, are containers for methods. But, unlike classes, traits have no fields. Traits, like abstract classes, cannot be instantiated directly; instead, they are composed into classes (which are instantiable).

Presence of Type Based Overloading

Constructor and method overloading is a type of polymorphism where different functions with the same name are invoked based on the data types of the parameters passed.

```
class VehicleUtilities {
        int numberOfAxles(Vehicle v) { return 2;}
        int numberOfAxles (Truck t){ return 3;}
}
```

In general, overloading means that a function name or an operator has two or more distinct meanings. When you use it, the types of its operands are used by the language to determine which meaning should apply. In Java, the programmer can declare several different functions, in the same scope, with the same name, but different parameter types. A call using this function name is resolved at compile time to one of the several functions by looking at the types of the actual parameters (Gosling *et al*., 2005).

Problems with type based method overloading include:

Risk of ambiguity

In most overloading schemes, you can create situations where you cannot decide which method to call and therefore declare the call illegal. Unfortunately, as the type hierarchy evolves, legal code can become illegal, or simply change its meaning. This means that existing code breaks when you recompile, or does the wrong thing if you do not.

Overloading is open to abuse

It allows you to give different operations the same name.

Overloading makes it hard to interoperate with other languages.

It's harder to call the overloaded methods from another language. Such a language may have a different type system and/or different overload rules.

Dynamic language

JRuby (Nutter *et al*, 2010) implement multimethod dispatch to approximate the behavior of overloaded methods it needs to call. This is costly at run time, and is a burden on the language implementer.

Overloading adds complexity to the language

It tends to interact with all sorts of other features, making those features harder to learn, harder to use, and harder to implement. In particular, any change to the type system is almost certain to interact with type based overloading.

case studies 8.0

Static Variables : Scala Compiler 8.1

This section is based on the experience of the Scala Team in the implementation of two different versions of the Scala compiler as described in the paper Scalable Component Abstractions (Odersky and Zenger , 2005). The Scala compiler consists of several phases. All phases after syntax analysis work with the symbol table module. The table consists of a number of modules including, names module that represents symbol names. A name is represented as an object consisting of an index and a length, where the index refers to a global array in which all characters of all names are stored. A hashmap ensures that names are unique, i.e. that equal names always are represented by the same object; symbols modules that represent symbols corresponding to definitions of entities like classes, methods, variables in Scala and Java modules; a module Types that represents types, and a module definitions that contains globally visible symbols for definitions that have a special significance for the Scala compiler. Examples are Scala's value classes, the top and bottom classes Scala.Any and Scala.All. The structure of these modules is highly recursive. For instance, every symbol has a type, and some types also have a symbol.

In previously released versions of the Scala compiler, all modules described above were implemented as top-level classes (implemented in Java), which contain static members and data. For instance, the contents of names were stored in a static array in the Names class. This technique has the advantage that it supports complex recursive references. But it also has two disadvantages. Firstly, since all references between classes were hard links, the compiler classes could not be treated as components that can be combined with different other components. This prevented piecewise extensions or adaptations of the compiler. Second, since the compiler worked with mutable static data structures, it was not re-entrant, i.e., it was not possible to have several concurrent executions of the compiler in a single VM. This was a problem for using the Scala compiler in an integrated development environment such as Eclipse.

The Scala Team solved the above problem introduced by static references through the use of nested classes and doing away with static references. In that way, they arrived at a compiler without static definitions. The compiler is by design re-entrant, and can be instantiated like any other class as often as desired.

Method Lookup Strategy : Newspeak Programming Language 8.2

In the paper (Bracha, 2010), Gilad Bracha provides his experience on the implementation of method lookup mechanism for the Programming Language Newspeak. Newspeak is a dynamically typed class based language which is a descendant of Smalltalk. The paper presents alternative interpretations of the semantics of method lookup:

(i) Require all sends to have an explicit receiver as in Smalltalk. The problem with this solution is that it's overly verbose.

(ii) Require outer sends to have an explicit receiver. This also solves the problem.

(iii) Require all self sends to have an explicit receiver. Given that outer sends have an implicit receiver, it makes no sense to treat locally defined self sends differently, so we interpret this as only requiring all inherited self sends to have an explicit receiver.

(iv) Retain implicit receivers for both self sends and outer sends, but reverse the priority so as to favor sends to names with locally visible definitions. In Newspeak an identifier refers to the nearest lexically visible declaration, subject to overriding by subclasses. If no lexically visible

binding exists, they interpret it as a self send. If one wishes to refer to an inherited method of an enclosing class, an explicit outer send expresses this intent unambiguously.

Uniform Object Model 8.3

Kava: In OOPL there has always been distinction between" primitive" or "built-in" and user defined types. The paper (Bacon, 2003), shows how an object-oriented language can be defined without any primitive types at all, and yet achieve the same run-time efficiency as languages that make use of primitive types (at the expense of greater compile-time effort). The authors' quote the following as advantages of having a uniform object model in a language:

(i) The programming model is simplified because the distinction between primitives and objects has been removed; and

(ii) The language design is simplified and more easily verifiable because a larger amount of the language is in libraries, and there is no need for large numbers of rules for primitive types that must be included in the language specification and verified on an ad-hoc basis.

Scala: The paper (Odersky et al, 2006) describes how Scala uses a pure object-oriented model. Every value is an object and every operation is a message send.

(iii) **Classes** Every class in Scala inherits from class *Scala.Any*. Subclasses of *Any* fall into two categories: the value classes which inherit from *scala.AnyVal* and the reference classes which inherit from *scala.AnyRef*.

(iv) **Operations** Another aspect of Scala's unified object model is that every operation is a message send, that is, the invocation of a method. For instance the addition **x + y** is interpreted as **x. +(y)** i.e. the invocation of the method **+** with **x** as the receiver object and **y** as the method argument.

Language Syntax and Semantics 9.0

The language syntax and semantics is based on C, C++, C# and Java family but with a few differences, i.e., in variable declaration, the type comes after the variable name and not before e.g. *var i:int* instead of *int i*. This is useful in type inference; addition of Traits (Scharli et al, 2003) to the type system; unlike C#, C++ and Java, there is no separation of computation into *Expressions* and *Statements*; these are unified into Expression; no support for static variable and static methods; uniform object model, there is no dichotomy of primitive and non-primitive types.

Lexical Structure 9.1

The Lexical Structure of the language closely resembles that of Java; in particular

(i) *Line Terminators*: Lines are terminated by the ASCII characters CR, or LF, or CR LF.

(ii) *White Space*: White space is defined as the ASCII space, horizontal tab, and form feed characters, as well as line terminators.

(iii) *Comments*: Supports both single-line comments and multi-line comments

(iv) *Identifiers*: can be composed of a sequence of characters beginning with an alphabet and followed by alphabets or digits

(v) *Keywords*

(vi) *Literals*: There are four types of literals: Integer, Floating Point, Boolean, Character and String literals.

Type System 9.2

The language has a nominal type system (Pierce, 2006) with some elements of structural typing. In particular, it has the following kind of types:

(i) *Class types*: The Class Type is introduced through a Class declaration. The name of the Class is the type. A class type **e** is a subtype of every type that appears on its extends clause.

(ii) *Trait types*: The Trait Type is introduced through a Trait declaration. The name of the Trait is the type. A trait type is a subtype of every type that appears on its extends clause.

(iii) *Function types*: The Function type is introduced through block closure declaration.

Declarations 9.3

(i) *Compilation Unit*: A Compilation Unit consists of a package declaration, followed by a sequence of type definitions.

CompilationUnit ::= package QualId ;
[TopStatSeq]
TopStatSeq ::= TopStat {; TopStat}
TopStat ::= {Modifier} TypeDef

(ii) *Programs*: A program is a top-level class that has the method *main* of type *Array[String]Unit*. Program execution begins from the main method.

(iii) *Class Declaration*: The syntax for class declaration:

ClassDef ::= id [Modifier] ClassParamClause
[ExtendClause] ClassBody
ExtendClause ::= extends TraitTypes
TraitTypes ::= TraitType {, TraitType}
ClassParamClause ::= ([ClassParams])
ClassParams ::= ClassParam {, ClassParam}
ClassParam ::= [{Modifier} (val | var)]
id : ParamType [= Expr]
*Modifier ::= (**public**|**protected**|**private**)*
ClassBody ::= { [ClassBodyDecls] }
ClassMemberDecl ::= FieldDecl
| MethodDecl

| ConstructorDecl
| FunctionDecl
| ClassDef

A Class declaration has the following components (in the given order):

(i) *id* : The name of the class.

(ii) *modifier (Optional)*: This restricts the visibility of the class constructor.

(iii) *ClassParamClause*: Contains a list of formal value parameters for the default constructor. The scope of the formal parameter is the whole class declaration id.

(iv) *ExtendClause (optional)*: A List of well-formed trait names that are accessible from this class declaration.

(v) *ClassBody* : Defines the class members i.e. fields, methods, constructors and nested class definitions

Trait Declaration 9.3.1

TraitDef ::= id [TypeParamClause]
[ExtendClause] TraitBody
ExtendClause ::= ***extends*** *TraitTypes*
TraitTypes ::= TraitType {, TraitType}
TraitBody ::= { [MethodDecls] }

A Trait declaration contains the trait name followed by an optional type parameter clause and an extend clause finally followed by the trait body. When a trait extends others, it means that it inherits the methods from those traits, and that the type defined by that trait is a subtype of the types of traits it extends.

Expressions 9.4

We give an overview of the expressions in the language, namely:

a. *Instance Creation Expression*: Instance Creation Expression has the form new c where c is a constructor invocation. Let *T* denote the type of *c,* then *T* must denote a non-abstract subclass of *Object*.
SimpleExpr ::= new Id([Exprs])

b. *This and Super*
SimpleExpr ::= [id .] this
| [id .] super . id

this refers to the object reference of the inner most class or trait enclosing the expression. The type of *this* is the type of the class or trait. A reference *super.m* refers statically to a member *m* in the super-type of the innermost class or trait containing the reference. It evaluates to a member *m'* that has the same name as *m*.

c. *Method Invocation*:
Expr ::=id([Exprs])
Exprs ::= Expr {, Expr}

A Method Invocation expression has the form $e.m(e_0,...,e_n)$.The expression *e*, if present, must evaluate to an object expression. Let the expression *e* have the type *T* given by the definition *D*. Then:

a. *D* must be either a Trait or a Class.
b. Further, *D* must define a method of the form $m(e:T_0,...,e_l: T_l)$.

where:

- *l* must be equal to *n*
- for every *i* in *0...n*, the type of the parameter value expression ,*e* in $e.m(...,e_i,...)$ must conform to the expected type of the corresponding formal parameter declaration $m(...,e_i:T_i,...)$.

If the method invocation expression has the form $m(e_0,...,e_n)$.

Then search for *m* in the following order:

- Search for a field named *m* in the enclosing class declaration.
- If *m* is a field, then its type must be function type and the expression is a *Lambda Invocation* .
- Else, search for a method named *m* recursively in the outer class enclosing this class declaration if any.
- If not found, search the Traits that this class extends for a method named *m*.
- If still not found, return the error *method not found*.

d. *Blocks*

Block ::= {BlockStat ;}
BlockStat ::= Def
| {LocalModifier} TypeDef
| Expr1

A Block expression has the form $\{s_0,... s_n, e_0\}$. The result of evaluating the Block expression is the value of the evaluation of the last expression in the block. The type of the last expression in the block must conform to the type of the Block expression. Let the expected type of the Block expression $e = \{s_0,...,s_n,e_0;\}$ be *T*, then the type of the expression e_0 must conform to *T*.

e. *Assignments*

[SimpleExpr .] id = Expr

An Assignment Expression has the form $x = e$ .The assignment changes the current value of *x* to be the result of evaluating the expression *e*. The type of *e* is expected to conform to the type of *x*.

f. *If Expressions*:

if (Expr) { Expr } [else { Expr }]

An if expression has the form: *if* (e_0) e_1 *else* e_2.The expression e_0 must conform to a Boolean type. The type of the expression e_1 and e_2 must conform to the expected type of the *if* expression.

The expression to be executed is chosen based on the results of the evaluation of the *Boolean* expression e_0

g. *While Loop Expression*

while (Expr) { Expr }

A While loop has the form $while(e_0)\{ e_1\}$.The expression e_1 is repeatedly evaluated until the evaluation of the expression e_0 results in a false value. If e_0 evaluates to false, then the expression e_1 is not evaluated. The type of the expression e_0 must conform to a *Boolean* type. The type of the e_1 expression must conform to the type of the while expression.

h. *Do Loop Expressions*

do { Expr } while (Expr)

A Do Loop has the form $do\{e_1\}while(e_0)$.

The expression e_1 is evaluated; if e_0 evaluates to false, the expression e_1 is not evaluated. Otherwise the expression e_1 is repeatedly evaluated until the evaluation of the expression e_0 results in a false value. The type of the expression e_0 must conform to a *Boolean* type. The type of the e_1 expression must conform to the expected type of the do loop expression.

i. *Lambda Expression*

Expr ::='#'(Bindings) => Expr
Bindings ::= (Binding {, Binding})
Binding ::= id : Type

Lambda Expression has the form $\#(p_0: T_0,...,p_1: T_n) \Rightarrow e$.

The formal parameters $\#(p_0: T_0,...,p_1: T_n)$ must be pairwise distinct. The scope of the parameters is the expression *e*. The expression must conform to the expected type of the Lambda expression.

Compiler 10.0

The compiler is written in Java. It compiles programs and generates JVM bytecodes (Lindholm and Yellin, 1999) which can execute on the JVM. The compilation is done over a number of phases. These phases include:

Lexical Analysis 10.1

The source program is transformed to a stream of tokens: symbols such as identifiers , literals, operators, keywords and punctuation. Comments and blank spaces are discarded.

Parsing 10.2

The parser constructs the Abstract Syntax Tree(AST) from the token stream.

Semantic analysis 10.3

Name Analysis: When defining a name if the name is already in the local environment: the identifier is already declared. Else, the new name is inserted in the environment. When looking up a name, first look in the local environment. If it is found we are done, otherwise repeat in the next environment on the search path. If there are no more environments the identifier is not declared.

Name analysis algorithm 10.4

(i) Build a global class and trait environment.
(ii) Resolve uses of types.
(iii) Check well-formedness of the class hierarchy.
(iv) Disambiguate uses of names.
(v) Resolve uses of locals and formals variables.
(vi) Resolve uses of methods and fields.

Type Analysis: The part of the compiler that does the type analysis is called a ***typechecher***. The Typechecker performs the following tasks:

(i) Determine the types of all expressions.
(ii) Check that values and variables are used consistently with their definitions and with the language semantics.

Type checking is performed bottom-up on the AST.

Reachability Analysis

This phase involves carrying out a conservative flow analysis to make sure all statements are reachable. There must be some possible execution path from the beginning of the constructor, method or instance initializer that contains the expression to the expression itself.

Definite (un)assignment analysis: consists of two parts, I.e., DefAssign where each local variable and every blank *val* must have a definitely assigned value before any access of its value occurs and DefUnassign where every blank *val* variable must be assigned at most once; it must be definitely unassigned when an assignment to it occurs.

Uncurry/Closure Conversion: Closure conversion transforms a program in which functions can be nested and have free variables into an equivalent one containing only top level functions.

Algorithm

The closing of functions through the introduction of environments. Functions are closed by adding a parameter representing the environment, and using it in the function's body to access free variables. Function abstraction must create and initialize the closure and its environment; Function application must extract the environment and pass it as an additional parameter.

The hoisting of nested, closed functions to the top level. Once they are closed, nested anonymous functions are hoisted to the top level and given an arbitrary name. The original occurrence of the nested function is replaced by that name.

Bytecode Generation

The input to the bytecode generation is an attributed AST. The algorithm traverses this AST generating bytecode for each of the constructs found in the tree. The algorithm uses object web byte code generation library.

Related Work 10.5

The concept of traits were first introduced by Smalltalk, but the version used here is based on (Scharli et al, 2003; Scharli *et al*., 2002).

The syntax closely follows that of Scala (Odersky *et al*., 2008)

Object based encapsulation is an extension of the one implemented in Scala (Odersky *et al*., 2008) and also an adaptation of the one in Newspeak.

Elimination of static state is partly an adaptation of work by Bracha (Bracha, 2010) in which he does the same for his *dynamically typed language*. In this paper, the same idea is applied to *statically typed language*.

Uniform object model was inspired by Smalltalk (Goldberg and David, 1985), Newspeak(Bracha, 2010) and Scala (Odersky *et al*., 2008).

In implementing the compiler, a lot was learnt from browsing *javac* compiler source code from the OpenJDK project and Fortress project.

Conclusion and Further Work 11.0

We have presented several programming language constructs that we believe when used in large software projects they can lead to software that is of poor quality. We then demonstrated by use of four case studies the problems caused by some of the constructs based on real life large software projects. Each of this construct is avoided in some of the existing Statically Typed Object Oriented Programming Language, but we believe we are the first to eliminate all of them in one STOOPL language.

There are several issues that need to be addressed through further research, i.e., a formalization of the design of the language along with proofs of type safety and implementation of a production quality compiler.

Acknowledgment

Special thanks to both of my supervisors Dr.Waweru Mwangi and Dr. John Mathenge Kanyaru for numerous helpful discussions and feedback.

References

Ackerman, W. B.and Jack B. D. (1979). VAL: a Value oriented Algorithmic Language.

Ancona, D., Lagorio, G. and Zucca, E. (2000). Jam --- A Smooth Extension of Java with Mixins. **In** ECOOP00 European Conference on ObjectOriented Programming. Springer, pp. 154-178.

Cambridge, MA: Massachusetts Institute of Technology, Laboratory for Computer Science.

Bracha, G. (2010). On the Interaction of Method Lookup and Scope with Inheritance and Nesting. Language.

Bracha, G.and Cook, W. (1990). Mixin-Based Inheritance. In ACM Sigplan Notices. ACM, pp. 303-311.

Barendregt, H. P. (1981). The Lambda Calculus its Syntax and Semantics, North-Holland.

Barnes, J. (2008). Ada 2005 Rationale, Springer.

Bacon, D. F. (2003). Kava: a Java dialect with a uniform object model for lightweight classes. Concurrency and Computation: *Practice and Experience,* **15**(35), pp.185-206.

Boehm, B. W., Brown, J. R. and Lipow, M.(2008). Quantitative evaluation of software quality.

Cielecki, M., Fulara, J. and Jakubczyk, K. (2006). Propagation of JML non-null annotations in Java programs. of programming in Java.

Cardelli, L. (1996). Type systems. *ACM Computing Surveys*, **28**(1), pp.263-264.

Clocksin, W .F. and Mellish, C. S. (1981). Programming in Prolog, Springer-Verlag.

Chivers, I. and Sleightholme, J. (2005). Introduction to Programming with Fortran: With Coverage of Fortran 90, 95, 2003 and 77. Springer: London, U.K. Springer, 2006. Print.

Dahl, O. J., Myrhaug, B. and Nygaard, K., (1968). SIMULA 67. Common Base Language.

Goldberg, A, and David R. (1985). Smalltalk-80: The Language and Its Implementation. Reading, MA: Addison-Wesley.

Gosling, J. (2005). The Java Language Specification, Third Edition, Addison Wesley.

Halloway, S. (2009). Programming Clojure S. Davidson Pfalzer, ed., Pragmatic Bookshelf.

Harrison, M.(1967). The Programming Language LISP: Its Operation and Applications, MIT Press.

Kernighan, B. W. and Ritchie, D. M. (1978). The C Programming Language, Prentice Hall.

Milner, R., Tofte, M. and Harper, R. (1990). The Definition of Standard ML, MIT Press.
Odersky, M. and Zenger, M.(2005). Scalable component abstractions. ACM SIGPLAN Notices, **40**(10), p.41.

Odersky, M. (2006). An Overview of the Scala Programming Language, Second Edition.

O'Sullivan, B., Goerzen, J. and Stewart, D. (2008). Real World Haskell, O'Reilly Media.

Scott, M. L. (2000). Programming language pragmatics, Morgan Kaufmann Pub.

Stroustrup, B.(1997). The C++ Programming Language, Addison-Wesley.

Lindholm, T. and Yellin, F. (1999). The Java Virtual Machine Specification, Addison-Wesley.

Rossum, G. V. and Drake, F. L. (2010). Unicode HOWTO. History, **172**(7), p.10.

Scharli, N. et al. (2003). Traits: Composable units of behaviour. ECOOP 2003–Object-Oriented Programming, p. 327–339.

Schärli, N. (2002). Traits: Composable Units of Behavior. Technical Report, 2743 (November 2002), pp. 248-274.

Nutter, C. (2010). Using JRuby, Pragmatic Programmers Pierce, B. C. (2002). Types and Programming Languages, The MIT Press.

Taivalsaari, A. (1996). On the notion of inheritance. ACM Computing Surveys, 28(3), pp.438-479.

Borning, A. H. and Ingalls, D. H. H.(1982). Multiple Inheritance in Smalltalk-80. In Proceedings at the National Conference on AI. pp. 234-237.

Keene, S. E. (1989). Object-Oriented Programming in Common-Lisp, Addison Wesley.

Meyer, B. (1997). Object-Oriented Software Construction, Second Edition, Prentice Hall PTR.

Schaffert, C. (1986). An Introduction to Trellis/Owl. In ACM Sigplan Notices. pp. 9-16.

Flatt, M., Krishnamurthi, S. and Felleisen, M.(1998). Classes and Mixins. In Conference Record of POPL98 The 25th ACM SIGPLANSIGACT Symposium on Principles of Programming Languages. ACM Press, pp. 171-183.

Mens, T. and Van Limberghen, M. (1996). Encapsulation and Composition as Orthogonal Operators on Mixins: A Solution to Multiple Inheritance Problems. Object Oriented Systems, 3(1), pp.1-30.

Moon, D. A., (1986). Object-Oriented Programming with Flavors. In N. Meyrowitz, ed. Proceedings of the Conference on ObjectOriented Programming Systems Languages and Applications OOPSLA. ACM Press, pp. 1-8. [52] David A. Moon. Object-oriented programming with flavors. In Proceedings OOPSLA 86, ACM SIGPLAN Notices, volume 21, pages 18, November 1986.

INTEGRATING ICT WITH EDUCATION: DESIGNING AN EDUCATIONAL COMPUTER GAME FOR TEACHING FUNCTIONS IN UNDERGRADUATE MATHEMATICS

R. W. Mwangi, R. Waweru and C. W. Mwathi
Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: rosamwangi@yahoo.com

Abstract
This research seeks to look into the design process that promotes the development of an educational computer game that supports teaching and learning processes. The research specifically looks at the design of an educational computer game for teaching and learning of the topic of functions. The topic is essential in the teaching and learning of Mathematics courses such as Discrete Mathematics, Real Analysis and Calculus among others at Jomo Kenyatta University of Agriculture and Technology (JKUAT) Kenya. The computer game was developed using the Basic Unified process (BUP) which is a streamlined version of the rational unified process (RUP). This is an object oriented methodology mostly used for small projects with few end users. Due to the few numbers of end users we used interview method of data collection to gather requirements for the computer game. A paper prototype was used to validate the requirements. Use cases were used for both analysis and design of the game while Class diagrams and activity diagrams were purely used for the design of the game. Owens' six top level design anatomy aided in the design of the computer game. The overall computer game design was based on Crawfords' computer game design sequence model. The well designed and developed game met all its user requirements and was able to facilitate the teaching and learning of functions to Bachelor of Science in Mathematics and Computer Science students who were taking Discrete mathematics in their first year of study at JKUATs' Taita/Taveta campus. Development of heuristics for measuring interest, fun and motivation are recommendations given to aid in the evaluation of user satisfaction of educational computer games.

Key words: ICT, educational computer games, computer game design, functions

1.0 Introduction

(Klopfer *et al*., (2009), asserts that "technology can have a reciprocal relationship with teaching. The emergence of new technologies pushes educators to understanding and leveraging these technologies for classroom use; at the same time, the on-the-ground implementation of these technologies in the classroom can (and does) directly impact how these technologies continue to take shape." How well an educational computer game is designed determines the level of success of use in the classroom setting. This research lays particular emphasis on the design of a game with an educational component to it. It stresses on the importance of developing a well designed computer game that will not only entertain the student but also support the teaching and learning process. To support teaching and learning a computer game must create an appropriate mapping of education and engagement. The computer game developed followed a formal systems development methodology called Object Oriented systems development.

Objected oriented systems analysis and design approach was used for the analysis (requirements engineering) and design of the computer game. Object oriented approach views information systems as a collection of interacting objects that work together to accomplish tasks. Objects are things in a computer system that can respond to messages. Object oriented approaches include the rational unified processes and the basic unified process which is a streamlined version of the rational unified process. The basic unified process was used since it is a process that focuses on practices suited to most small projects and teams.

Basic unified process method content is focused on the following disciplines: requirements engineering, architecture (analysis and design), development, testing, project management and change management.

The computerized game is developed using full professional acrobat reader version 9 and games' logic and control is embedded adobe java script a type of java script customised for adobe documents.
This research paper looks at the design of the computer game which in BUP is intertwined with analysis phase.

2.0 Requirements Engineering

Requirements engineering is a process whereby the requirements for the computer game are gathered from the users and analysed. Three lecturers from the Department of Mathematics at Jomo Kenyatta University of Agriculture and Technology (JKUAT) provided a set of problems (requirements) which translated into the computer game functionality. This was an iterative activity which included documenting the requirements the computer game was to provide, analysis of the requirements for any possible omissions, contradictions and ambiguities and review of the requirements after validation before moving to the design stage.

A paper prototype of the computerised game was generated using Microsoft word. This paper prototype simulated the user interface as it would appear to a player on a computer screen and the developer walked the users through to make sure all the requirements had been captured.

3.0 Anatomy and Design of the Developed Game

This section looks into the design of the computer game for teaching and learning function from Owens' design anatomy of a computer game. According to (Owen, 2004), 'Anatomy is a study that arises from dissection'. An anatomy of the game aided in better design of the computer game. Owen, (2004) bases anatomy on six top-level categories of game components: game aims; game location; game pieces/players; the means of making progress in the game; game language; and the

time frames of games. It is on these six levels that the computer game for teaching functions is based on. The game has five levels as shown in the following class diagram

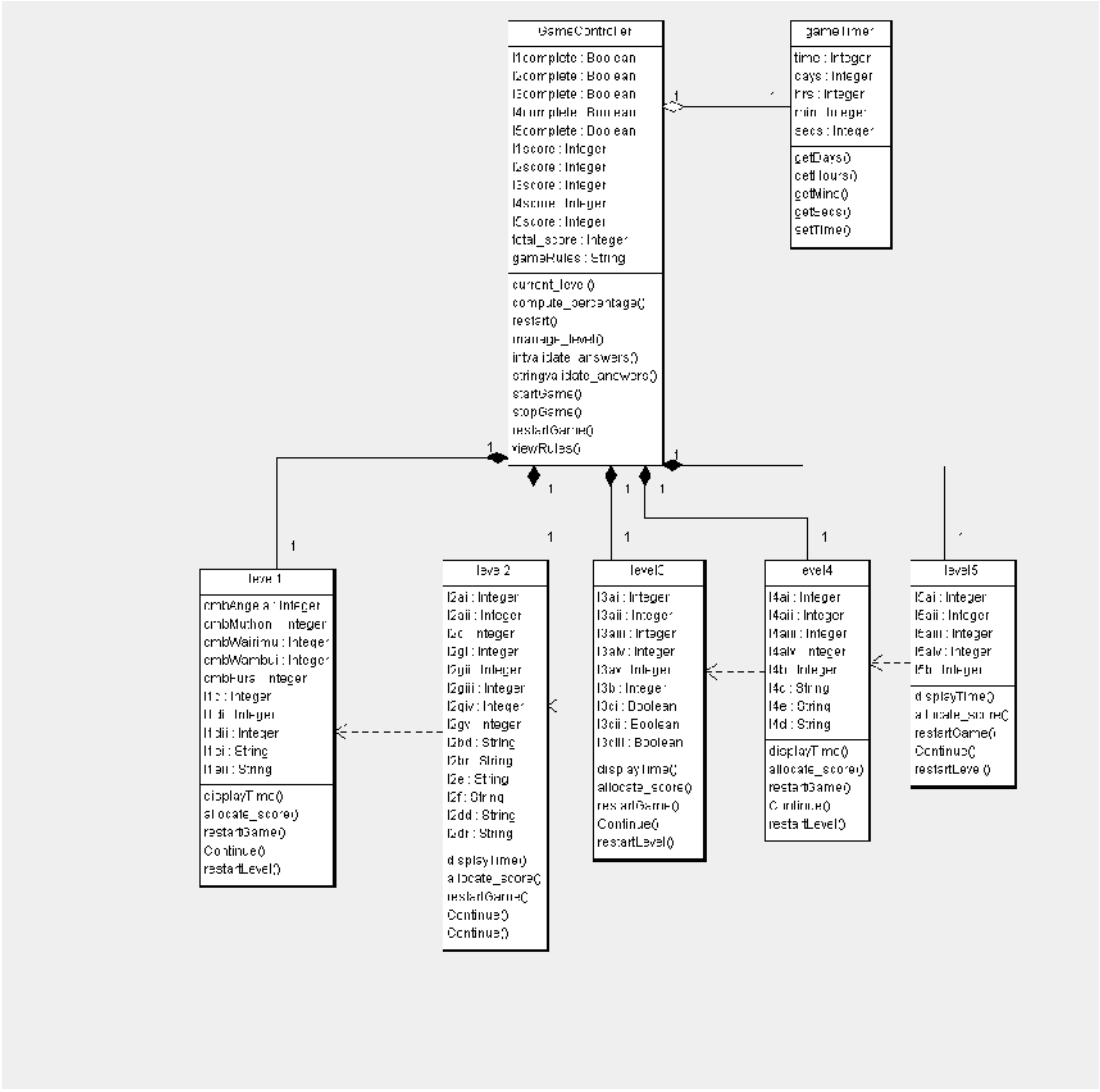


Figure 1: Class Diagram

Game Aims 3.1

Any computer game must have aims which should be achieved. Rules and objectives form part of the aims of a game. (Owen, 2004) recognises that in many games a strong fantasy and/or narrative are important and that in all games there is also a set of objectives that give rise to the nature of the game activity – the Gameplay'. In the developed computer game the aim of the game is to play all the five levels and achieve a minimum of 60% in each level in order to progress to the next level. A player cannot proceed to another level until he or she achieves a minimum score of 60%. *Figure 2* shows an UML activity diagram that was produced to design the computer game rules. Screen shot 1.0 show the actual screen on the computer game where the game rules are displayed before the game starts.

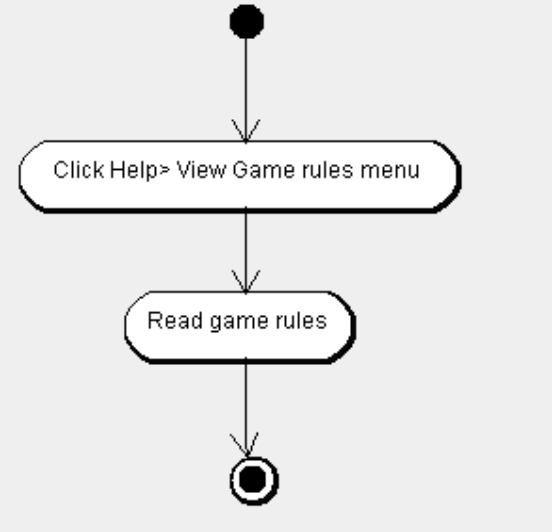


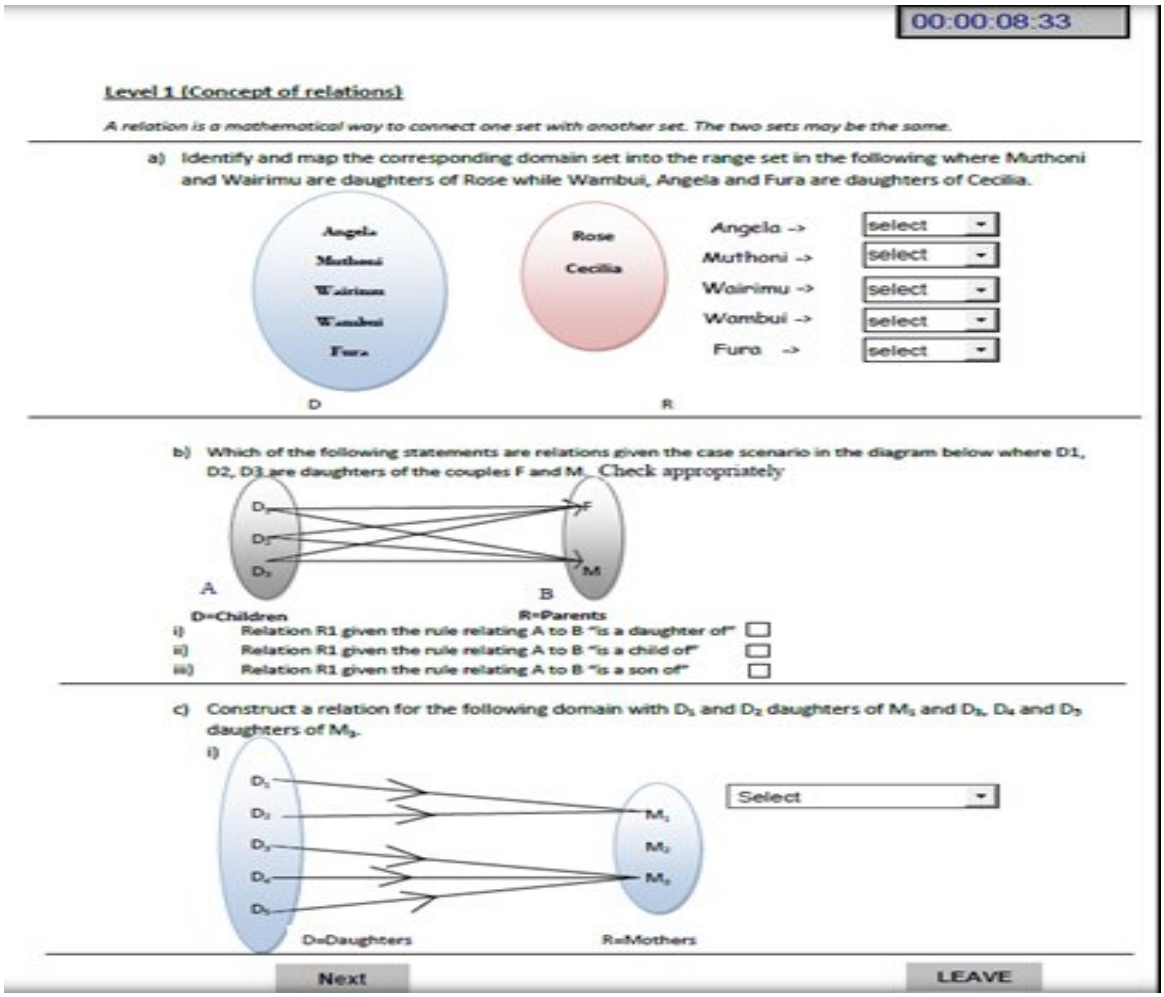
Figure 2: Game rules activity diagram

Screen Shot 1.0

3.2 Location

Location is an important component in computer game play. Owen (2004) points out that 'Games can take place in real spaces, virtual spaces and some games do not involve any particular space at all'.

Real space may be bound, unbound or augmented. Virtual spaces may include audio and visual screens, boards and mazes. In the developed computer game paper diagrams have been simulated on computer screen and interface provided where the user interacts with the game as would on paper. This is shown in Screen Shot 2.0 below.



Screen Shot 2.0

Non-location specific games can be played anywhere for example in a car, a school play ground. For computerised games it can be on any platform that is any type of operating system, hardware, online or offline, web based etc.

3.3 Game Pieces/Players

A piece means anything that is engaged in the play. It could be a simple counter, human player, a proxy item a token, a drop down menu with a list of possible answers for a quiz, a blank space that could be used to provide an answer or instruction, a blinking object etc. There is uniformity in pieces in a game. In the developed game the pieces include the player, the quiz questions and answers, blank spaces for putting down answers, drop down menus with answers and diagrams. In object Oriented design the pieces and players are represented by actors and uses cases in a use case diagram. The actors and the use cases for the computer game are shown in the following two use case diagrams: *Figure 3* game play use case diagram and *Figure 4* game control use case diagram. The game play use case shows two actors and five use cases. While the game control use case has two actors and four use cases.

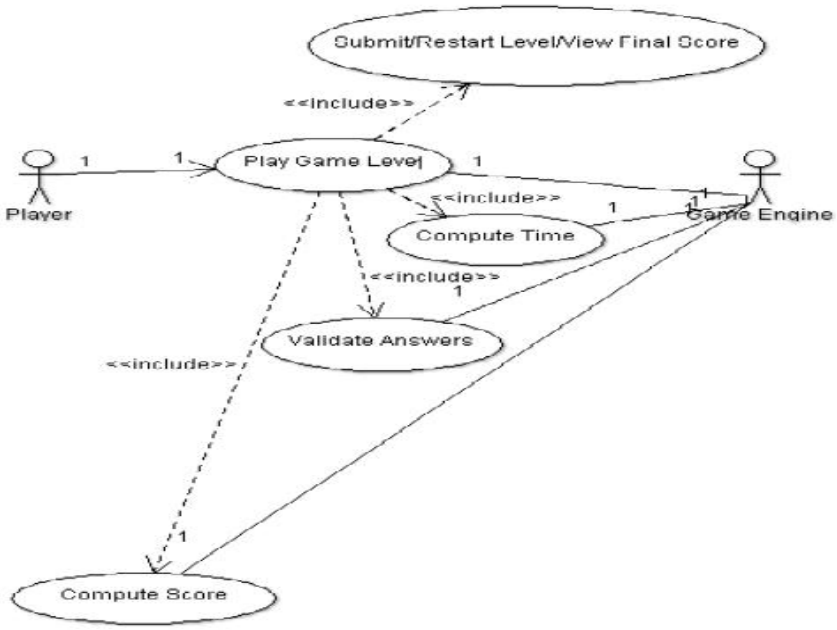


Figure 3: Play game use case

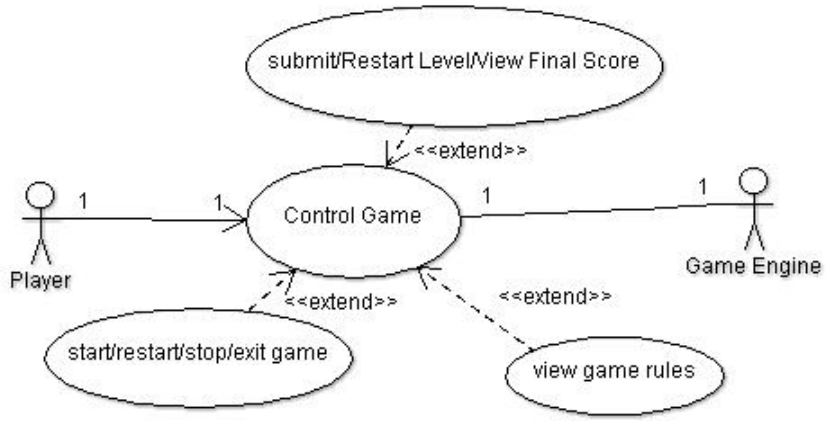
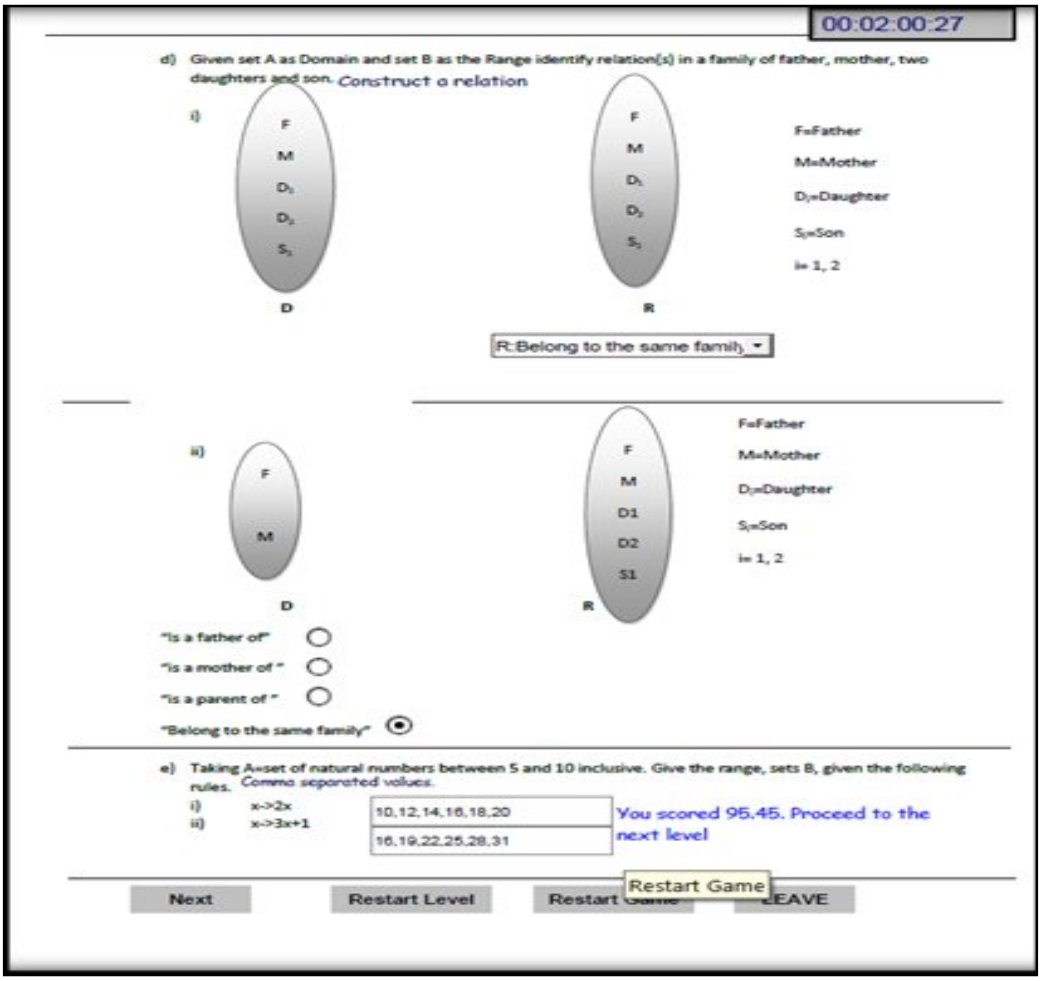


Figure 4: Game control use case

3.4 Language

A computer game should make use of language specific to the simulated physical game or activity in the case of the computer game for teaching and learning functions. The developed computer game makes use of mathematical terms used in the teaching of functions see screen shot 3.0 below. This makes the game easier to learn and play by students taking the mathematics course since they do not have to learn new terms to play the game. This is also referred to as transfer of learning.



Screen shot 3.0

3.5 Time

In most computer games timing and speed are part of the gaming process. Some computer games allow a player to complete the level even when one does not play in the required time given but of course marks for time are not awarded or in some instances one is penalised for taking too long to play a game. Some computer games lock out a player out of a session once the time elapses and the level has to be replayed. In the developed computer game since it is a game that is meant to aid acquisition of knowledge the timing has been provided but that's meant for the players to see how long they have taken to play the game. Once the player completes the entire game that is all the five levels the aggregate marks for the five levels are displayed including the time taken to play the game. The timing component was designed as a use case as illustrated in fig ***3*** play game use case above.

3.6 Making Progress

Jour

neying towards the achievement of a game goal is the most important goal in any computer game. There are many factors that may influence how one progresses from one level to another. This may include according to (Owen, 2004) random elements; physical effort (with and without the support of other devices); solving puzzles; answering quiz questions; and cheating. In the developed computer games factors that affect the journeying towards the achievement of the goal include first the physical effort that is speed of typing, second level of computer literacy skills and third mastery

of the subject content, those who have prior knowledge of functions were able to answer most of the questions correctly and therefore getting the required minimum score for progressing to the next level. The computer game design incorporated a definition for the subtopic for each level to aid the students in remembering the subject. The structure of the game is illustrated in Figure 5 Start to Stop Activity Diagram below

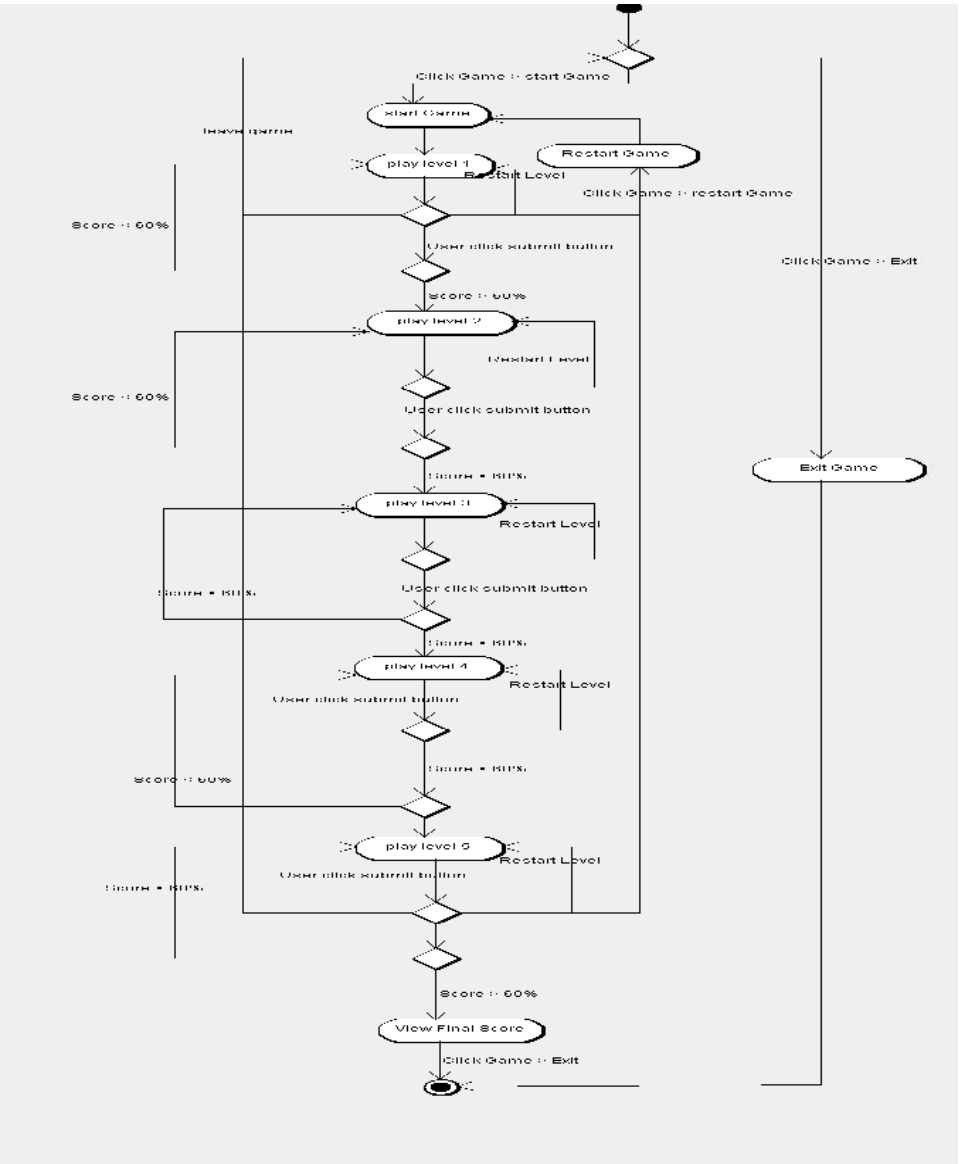


Figure 5: Start to stop activity diagram

3.1 Model Used for the Design and Development of the Computer Game for Teaching Functions

From literature review that has been conducted there is a general consensus that for instructional computer games to be effective they must be designed to support instructional objectives. Proper and systematic analysis and design of computer games facilitates learning of both specific domain knowledge and concepts, and several cognitive skills like pattern recognition, decision-making and problem-solving. There are a number of models that have been developed to be used for the development of instructional computer games. This research based it computer game development

on Craw fords' model. (Crawford, 1982) describes the computer game design sequence model as: choosing a goal and a topic, researching, designing, programming, play testing, and post-mortem.

4.0 Research Findings

Research findings indicate that well designed computer games are a success in their use in the classroom teaching and can prepare our students to learn critical problem-solving and decision-making skills necessary for the real world.

Computer games enhance motivation and increase students' interest in subject matter. Educational games have to be intrinsically motivating to appeal to the gamers. They should incorporate learning activity in a virtual world. (Maja et al, 2003**)** argues that for intrinsic games "Game characters have to solve a certain problem and can proceed further only after solving the problem. In this case the problem is part of the game and players are motivated to provide a solution in order to continue with the game". An example for intrinsic motivation in the computer game for teaching functions is where players have to achieve a minimum score of 60% in order to proceed to the next level. This intrinsic appeal of computer games is making them very attractive ICT tools for teaching and learning.

The developed computer game was not only entertaining but supported the teaching and learning of functions. This is supported by comments given by feedback and comments given by students who played the game see Table 1.0 below.

Table 1: Comments from the players after game play

Student	*Comments*	*Student*	*Comments*
Std001	Interesting game for learning how to solve Functions in Discrete Mathematics.	Std002	Has helped in having a deep understanding of relations and functions
Std003	Fun and educative	Std004	The game has a lot of fun and the same time making one to think critically and fast.
Std005	The game is so good. Actually it has made me understand functions more than what I had learnt before. It has also helped me to differentiate between one to one functions, onto functions and one to one and onto function.	Std006	The game is educative and helps in good understanding of the functions.
Std007	It's fun and educative more Mathematics games should be provided	Std008	The game is interesting to play and quite educative for learning purposes.
Std009	The game is very good. It has made me master functions and differentiate between functions and relations.	Std0010	A very interactive way of educating students in terms of showing/expressing skills learnt in class. Helps one understand better.

The computer game was able to create an appropriate mapping of education and engagement.

5.0 Conclusion and Recommendations

There are many issues that need to be addressed before the education sector can fully realise the full potential of using computer games as a way of integrating ICT with education. (Hui, 2009) states that "The greatest impetus is the tussle between commercialism and education. Most commercially-made computer games are based on some inaccurate, badly designed and often violent themes.

Particular characteristics and challenges of a computer game design raise concerns over design issues, educational aims of the game and the learning outcomes that educational designers should deal with. These challenges can only be overcome through careful design and development of the computer game. Thorough evaluation both for systems performances and whether the system meets its learning objective is needed for the computer game to realize its full potential in supporting teaching and learning.

Further studies might explore what makes computer games interesting, fun and motivating enough to support teaching and learning. Heuristics for measuring interest, fun and motivation could also be developed to aid in the evaluation of educational computer games.

References

Chang Suo Hui (2009). Learning mathematics through computer games. Retrieved from http://atcm.mathandtech.org/EP2009/papers_full/2812009_17199.pdf (Accessed 6th April 2009).

Crawford, C. (1982). The Art of Computer Game Design, Berkeley, CA: Osborne/McGraw-Hill, 77-92.

Klopfer, E., Osterweil, S, Groff, J, Haas, J. (2009). Using the Technology of Today in the Classroom Today; The Instructional Power of Digital Games, Social Networking, simulations and How Teachers Can Leverage Them: an Education Arcade paper. http://education.mit.edu/papers/GamesSimsSocNets_EdArcade.pdf (Accessed 31/10/2010).

Maja Pivec, Olga Dziabenko and Irmgard Schinnerl (2003). Aspects of Game- Based Learning.

Martin, O. (2004). An Anatomy of Games; A discussion paper. Futurelab September www.futurelab.org.uk. (Accessed 7 September, 2007).

SUB-THEME V

POLICY, GOVERNANCE, CULTURAL AND SOCIO-ECONOMIC ASPECTS OF DEVELOPMENT

ARE THERE SIGNIFICANT WELFARE OUTCOMES FOR FARMERS WHO PARTICIPATE IN GLOBAL COMMODITY CHAINS? THE CASE OF EXPORT HORTICULTURAL FARMERS IN KIRINYAGA REGION OF KENYA

F. N. Ondieki-Mwaura[1], L. M. Njoroge[2], J. J. Okello[3], J. M. Bahemuka[4]
[1,2]Department of Social Sciences and Humanities, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[3]Department of Agricultural Economics, University of Nairobi, Kenya
[4]Department of Sociology, University of Nairobi, Kenya
E-mail: fnmwaura@ihrd.jkuat.ac.ke

Abstract
The aim of this study was to determine whether farmers participating in export horticulture were better off than farmers who did not. This study is informed by debates on how globalisation and specifically global trade impacts on small farmers in third world countries, with proponents arguing that it has positive impacts and opponents arguing that participation in global commodity systems has little impact or ueven detrimental to small farmers. This study aimed to compare the welfare of participants in export horticulture with those of non-participants using both income and non-income indicators. A survey of 360 farmers was carried out in Kirinyaga to obtain household data with 240 export farmers and 120 non-export farmers being interviewed. Simple mean comparisons were used to determine whether significant differences existed between French bean and non-French bean farmers. Both income and non-income indicators were used to determine welfare outcomes for the two groups of farmers. The study found that there were some differences in welfare indicators between those who participatd and those who do not participate in French bean production, specifically in the type of housing, asset endowment and income. However, although export French beans,had a positive impact on participating farmers, its impact is declining as farmers' incomes from it are reducing.

Key words: Export farmers, non-export farmers, welfare outcomes, income, non-income indicators, French bean production

1.0 Introduction

Agriculture plays a key role in the livelihoods of a majority of people in developing countries, both in terms of providing food and income. For a number of these countries agriculture also provides a considerable amount of the much needed foreign exchange as well as creating employment for a significant proportion of the population. In recent times there has been recognition of the important role that agriculture can play in the reduction of poverty in rural areas where the poverty scourge is felt most intensely (Todaro, 1997; UNDP 2001). Agriculture therefore remains a vital sector not just in terms of economic growth but also as the key to eliminating poverty and unemployment in poor countries. As Gunnar Myrdal, Nobel Laureate in Economics quoted in Todaro (1997) articulates, '*it is in the agricultural sector that the battle for long-term economic development will be won or lost*'.

Kenya is among developing countries whose mainstay both in terms of foreign exchange, income and employment of its citizens is heavily reliant on agriculture. Close to 80% of Kenyans live in rural areas and derive much of their livelihood from land and agricultural activities. It generates 24% of the country's GDP and 18% of formal employment (RoK, 2007). The performance of this sector therefore significantly impacts not just on the economic aspect of Kenya's development but also on social and welfare aspects of a majority of its citizens. Welfare Monitoring Surveys (1994, 1997) indicate that 50% to 75% of Kenya's rural population lives in poverty and are dependent on major improvements in agriculture to raise their standards of living. Indeed the agriculture sector has been identified in Kenya's Poverty Reduction Strategy Paper (PRSP) as the one most likely to play a pivotal role in reducing poverty and increasing food security in the country (RoK 2004). One of the key challenges for the very poor (many of whom are agricultural producers) has been their limited access to markets not only in terms of acquiring goods and services but also in terms of selling their produce. Yet, countries that have made significant strides in reducing poverty, namely India and China have done so by improving poor peoples' participation in markets. One for the key elements therefore of a viable poverty reduction strategy is finding ways of including the poor as active participants in the market, whether local, regional or even international. In Kenya, such a strategy would involve improving access to markets including lucrative export markets of close to five million small agricultural producers, many of whom are considered poor (RoK, 2004; RoK, 2007). Such an inclusion should bring about the improvement of the well-being of these rural participants and should not be exploitative.

There are concerns especially from critiques of globalisation that the inclusion of poor producers into global commodity and value chains does not necessarily result in increased standards of living for the producers and the developing countries they are located in (Todaro, 1997). Infact, there is no agreement on whether inclusion of smallholders into high value commodity chains such as export horticulture benefits them or whether it locks them into exploitative relationships that do not favour them.

Some of the key benefits of including small farmers in globalised commodity chains through marketing arrangements such as contract farming as identified by various studies include improved access to credit and technical assistance improved access to lucrative export and domestic markets as well as increased incomes and employment opportunities. It also helps provide price stability to participants improved welfare and shorter lean periods. In addition, contract farming earns foreign exchange for countries that use it to develop cash crops.Contractual arrangements help to remove imperfections in produce, capital (credit), land, labour, information and insurance markets. They can also have positive spill-over effects on other crops grown by farmers through improved technology adoption and better resource management.

On the other hand, some of the concerns associated with trying to include smallholders in global commodity chains through contract farming for example are that they sometimes favour larger and wealthier farmers over small and poorer farmers thereby creating or exacerbating already existing inequalities in rural areas. Farmers from already marginalised sections of society too can also be locked out of contracts. For example, Sartorius & Kirstens (2006) indicate that as agribusinesses bypass spot markets and increasingly use arrangements based on trust and social networks, black farmers are increasingly being excluded from agricultural value-chains. Contractual arrangements can also lock small farmers into relationships that favour buyers especially when the former exercise monopolistic or monopoly powers. In some instances it has resulted in gender struggles over control of labour and resources resulting in the disruption of social order in the communities involved. It may also increase the burden of work for women and low pay. In some instances there has been increased use of child labour as well as casual employment in contract farming (Dolan 2001). At a macro-economic level, contract farming has sometimes led to food insecurity when there is a shift of production from basic food crops to export cash crops. Over-exploitation and degradation of environmental resources such as water and soil have been reported as a negative impact of contractual farming.

The impact of participating in contractual farming on the welfare of smallholders therefore ought to be determined on a case by case basis as the impacts could be either positive or negative. If globalised value-chains such as export horticulture are to contribute to helping improve the well-being of the poor in developing countries they must be an avenue for farmers not to earn an income but to earn an adequate income that will contribute to a significant improvement in their welfare.

1.0 Methodology

2.1 Study Area and Population

This study focused on farmers within Kirinyaga area, which has had a long history of growing this crop (Kyengo Per.Comm 2008). Kirinyaga region (which was formerly Kirinyaga District has now been split into 4 districts- Kirinyaga East, Kirinyaga West, Kirinyaga Central and Kirinyaga South Districts) and is situated on the southern slopes of Mt. Kenya. It covers an area of approximately 1478 sq. km with a population density of 309 persons per km^2, and an estimated population of 500,000 people (census 1999). It borders Nyeri and Murang`a to the West, Embu to the East and Mbeere to the south and is approximately 100 km, North-East from Nairobi.

2.2 Research Design

This study primarily used the survey type of research which is defined by Mugenda and Mugenda (1999) as an attempt to collect data and from members of a population in order to determine the current status of that population with respect to one or more variables. One of the main advantages of this approach is that it enables the researcher to collect original data for the purposes of describing a population which is too large to observe directly (ibid.). The survey approach was complemented by qualitative approaches namely case study, focus group discussions and key informant interviews. A case study according to is an empirical inquiry that investigates a contemporary phenomenon in-depth and within its real-life context especially when the boundaries between phenomenon and context are not clearly evident. The case method was used to gather in-depth information on the impact of participating in export French bean production on the welfare of these farmers.

2.3 Sample Size and Sampling Procedure

The field survey was carried out in August and September 2010.The sample size for this study was 240 farm households involved in French bean production and 120 households that did not participate in French bean production in 2009. The sampling procedure used for this study was stratified random sampling, in order to achieve a high degree of representation. The sub-location with the highest concentrations of French bean farms within each of the four districts was selected.

The exception to this is Kirinyaga South where three sub-locations were used accounting for almost 50% of the sample because this district alone accounts for about 50% of the total French bean production in Kirinyaga. Farmers lists were generated from these areas and households randomly sampled for the questionnaire survey. The table below summarises the sampling results.

Table 1: Sampling results

District	*Location*	*Sub-location*	*No. of French bean farmers*	*No. of Non-French bean farmers*
Kirinyaga Central	Kanyakine	Kathare	40	20
Kirinyaga West	Mwerua	Gitaku	40	20
Kirinyaga East	Kirima	Mutige	40	20
Kirinyaga South	Tebere Murinduko Kangai	Kiarukungu Kamunyange Gathiga	40 40 40*	20 20 20*
TOTAL			**240**	**120**

Source: Author

*Data for this sub-location is still being cleaned and analysed

2.4 Data Collection Tools

The data collection tools used included, a questionnaire that was administered to sampled households; key informant interviews with the District Horticultural officer, FPEAK official, farmer group officials and focus group discussion in every district.

2.5 Data Analysis

Data entry and analysis was done using Statistical Package for Social Sciences (SPSS). Descriptive statistics were used to analyse characteristics of the sample. Simple means were used to compare selected welfare indicators of growers and non-growers. Key informant interviews provided data were used give in-depth information on the nature and operation of these arrangements. The results presented below are preliminary results from the study.

2.0 Results and Discussions

The total number of respondents (excluding those from Kangai sublocation) was 300. The welfare variables used to compare growers and non-growers of French beans included income, total asset value (excluding the value of the land), access to safe drinking water, access to education, access to heathcare and clean sources of energy and good shelter.

3.1 Descriptives

In terms of infrastructure, the type of road to nearest market for sample, 48% of those who used non-paved-dirt road were 48% growers and 44.3% non- growers, for murram road there were 37.2% growers and 37.4% non-growers and for those who used a tarmac road to the market, 14.4% were growers while 18.3% were non- growers. In terms of the mean distance to the market, growers had an average of 3.2 km while non-growers had an average of 4 km. The mean distance to the nearest electricity hook-up was 1.08 km for growers and 1.8 km for non-growers. The mean distance to the nearest agricultural office was 8.16 km for growers and 8.44 km for non-growers.

In terms of the total acreage of land, the mean size for growers was 2.05acres while that of non-growers was 1.91 acres. The ownership rights for land for farm on title deed sub-divided but no title, leased and gifted were 30.5%, 48.1%, 18.2%, 3.2% respectively and for non-growers it was 37.3%, 50.9%, 8.2% and 3.6% respectively. The type of soil on the farms of growers was distributed as loam (75.5%), clay (.5%), and clayloam (23.9%). For non growers the distribution was 68.4%, .9% and 30.7% respectively. 95.7% of all French bean growers have irrigation compared to 60% of non-

growers. The most common type of irrigation used is furrow for both growers (67.8%) and non-growers (36.2%).

In terms of household composition, 83.4% of all grower households were male and female headed households compared to 77.2% of non-grower households. Growers had a mean of 9 years of schooling while non-growers had a mean of 8 years.

3.2 Comparisons of Total Asset Value and Type of Shelter

The total asset value was determined using various assets found in the household and included farm implements, household appliances, bicycles and cars among others. The respondent was asked determine the resale value and the total asset value was computed for every house the farmer owned. The mean asset value was Kshs. 178,489 for growers and Ksh.197,713 for non-growers. The value of the houses was computed separately and the mean value of houses for growers was ksh. 130,885 and that of non-growers was 150,362. The quality of shelter was assessed by looking at the type of floor, wall and roof of the farm house and the results are presented below.

Table 2: Type of floor

Type	*French bean grower*	*Non-grower*
Mud	110 (62.85)	65 (37.15)
Cement	69 (58%)	48 (41)
Tiles	0 (0)	1 (100)
	179	114

Table 3: Type of walls

Type	*French bean grower*	*Non-grower*
Stone	38 (62.3)	23 (37.7)
Bricks	11 (64.7)	6 (35.2)
Timber	85 (63.0)	50 (37.3)
Ironsheets	1 (100)	0 (0)
Mud	44 (55.6)	35 (44.3)
Total	179	114

Table 4: Type of roof

Type	*Grower*	*Non-grower*
Brick	0 (0)	1 (100)
Ironsheets	178 (61.16)	113 (38.83)
Grass Thatch	1 (100)	0 (1)
Total	179	114

There seems to be no significant difference in terms of the total asset value and type of housing between growers and non-growers from the evidence presented above. However, further statistical tests will be carried out to determine whether there is significant difference.

3.3 Access to Healthcare

Of the 55 respondents who reported having a member of their family as very sick in 2009, 33 (60%) were French bean growers and 22 (40%) were non-growers. 11 growers (68.75%) and 5 (31.25) non-growers sought treatment in private hospitals, 21 growers (55.2 %) and 17 non-growers (38%) sought treatment in public hospitals and only 1 grower sought treatment from a traditional herbalist. The main source of money for treatment for growers was French bean earnings and for non-growers it was the sale of other crops.

It was reported during the focus-group discussions that French bean earnings are important in meeting day to day family expenses such as health expenditures because French beans have a short maturity period and therefore farmers earn their money quickly. In addition, some of the farmer groups involved in French farming have invested in community health projects using earnings from French beans. A case in point is a maternity hospital that has been built near Karii town with money saved from French bean earnings by the Kangai Tisa Self-Help group. In 2006, they began saving Ksh.1 per kilo of produce sold and by 2008 they had collected Ksh. 6.5 million which together with a generous contribution from their buyer who matched their savings have now constructed the maternity hospital. Kangai Tisa's oversees buyer has also promised to supply them with equipment for the hospital worth Kshs. 4 million. French bean growers therefore have the potential of accessing good healthcare as individuals through their earnings or collectively through investing in projects that uplift the health of the general population as illustrated by the case of Kangai Tisa self-help group.

3.4 Access to Education

There were 195 households with children of school going age. Out of these 28 (68%) of the growers children attended private school while 13 (32%) of non- growers children attended private school. 101 children (65%) from French bean growing families and 53 children (35%) of children attended public schools. Of these 32 children (58%) from grower families and 23 children (42%) from non-grower families were sent home for lack of fees while 12 children from grower families (52%) and 11 (47.8%) from non-grower families were sent home for lack of uniform. The main source of money for fees, uniform and text books for French bean growers was French bean earnings while for non-growers it was the sale of other crops. While the results give a mixed outlook when comparing growers and non-growers with respect to education, French bean earnings contribute significantly to helping households access education for their children. For example, farmers ins self-help group can meet education expenses through to borrowing from the group sacco or against future earnings. In addition many groups do save a certain portion of their earnings that is paid out to farmers farmers at the end of the year as a bonus. This bonus is used by many farmers to pay school fees.

Sources of drinking water

Source	Grower	Non-grower
River	78 (66.6%)	39 (33.3%)
Water tank	2 (40%)	3 (60%)
Piped water	97 (58.4%)	69 (41.6%)
Well/borehole	11 (73.33%)	4 (26.66%)

The proportion of growers who use river water which can be considered as unsafe is much higher (78%) than non-growers (33%). More non-growers use water tanks than growers.

Sources of energy for cooking

Source	Grower	Non-grower
Firewood	177 (60)	114 (40)
Charcoal	10 (90.9)	1 (9.09)
LPG	1 (100)	0 (1)

The most commonly used source of energy for cooking by both growers and non-growers is firewood. Almost none of the households use LPG which is considered a lean and environmentally safe source of energy.

4.0 Conclusions and Recommendations

From the above results it would seem that there are not significant welfare outcome differences between growers and non-growers with respect to asset ownership, type of shelter, access to education and health. In fact in some cases it seems that non-growers have better outcomes than growers as in the case of access to clean water, total asset value and value of housing.

One of the major complaints of French bean farmers from the FGDs was that the price they received for French beans had remained constant for a long time yet the prices had doubled effectively reducing the income they earned. Therefore it is possible to conclude that this reduction in real income for farmers has limited their ability to improve their welfare as would be expected.

A strategy that should be encouraged for French bean farmers is to form group and leverage their numbers and earnings to invest in community projects that will uplift their communities as exemplified by the case of Kangai Tisa self-help group. In addition, as part of their corporate social responsibilities buyers of French beans can also directly invest in community projects that uplift the farmers and their communities.

References

Dolan, C., Humphrey, J. and Harris-Pascal, C. (2001). Horticulture commodity chains: the impact of the UK market on the African fresh vegetable industry. IDS Working paper 96.

Sartorius, K. and Kirsten, J. (2007). A framework to facilitate institutional arrangements for smallholder supply in developing countries: An agribusiness perspective in Food Policy Volume 32, Issues 5-6.

Benfica, R. M. S. (2006). An Analysis of Income Poverty Effects n Cash Cropping Economies in Rural Mozambique: Blending Econometric and Economy-Wide Models. Unpublished PhD Dissertation, Department of Agricultural Economics, Michigan State University.

Todaro, M. (1997). Economic Development 7th edition Addison Wesley Longman Limited.

Kenya, Republic, of (1994). Welfare Monitoring Survey II. Central Bureau of Statistics, Office of the Vice-President and Ministry of Planning and National Development, Nairobi Government Printers.

Kenya, Republic, of (1997a). Welfare Monitoring Survey III. Central Bureau of Statistics, Office of the Vice-President and Ministry of Planning and National Development,Nairobi Government Printers.

Government of Kenya (2001). Poverty Reduction Strategy Paper for the period 2001-2004. Go.

Government of Kenya: National Development Plan 2002-2008: Effective management for sustainable economic growth and poverty reduction, GoK.

Mugenda, O. M. and Mugenda, A. G. (1999). Research Methods: Quantitative and qualitative approaches. Acts press, Nairobi Kenya.

THE ROLE OF PROJECT MANAGEMENT IN THE SUCCESS OF PROJECTS UNDERTAKEN BY ENTREPRENEURS IN ELECTRICAL CONTRACTING SME

R. W. Gakure and W. G. Wako
Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya

Abstract
Studies have shown that project management skills are crucial for successful implementation of complex projects. However the impact of such skills in the SME sector in general and in the electrical contracting sub-sector especially in this part of the world is not well known. This study sought to identify the role of project management skills in the success of small electrical contracting projects. The study assessed the most important project management skills necessary for successful implementation, the extent of its use, the factors limiting their use and the relationship between their use and project success. The study was a census of the SME electrical contractors in Thika. Primary data was collected using semi-structured questionnaires. Analysis was done using descriptive statistics and data presented in tables, charts and narratives. Secondary analysis was conducted using Pearson's correlation. The research found out that the project management was a vital component in the success of any project. According to most respondents, project management was all about organizing the resources like time, labour and money in order to enable the work to run smoothly. This shows that they understand project management more than it was expected. The research also identified the factors limiting the use of project management skills and the relationship between the project management skills and success of the project. These included unqualified workforce, inadequate funds, and lack of honesty from the employees and clients, unavailable materials, limited time among others. The study made several recommendations which included among other things training of SME electrical contractors, educating the public, improvement in licensing of contractors, and encouraging entrepreneurs to invest in well stocked hardware stores in Thika.

Key words: Project management, project success, quality contracting, productivity, project management tool, customer satisfaction

1.0 Introduction

1.1 Background of the Study

Sessional Paper No.2 of 1992 on Small Enterprise and Jua Kali Development in Kenya defines a small and medium Enterprise (SME) as any enterprise employing between 1-50 employees. The importance SME has been emphasized in all development plans in Kenya since independence in 1963. The National Micro and Small Enterprise Baseline Survey of 1999 found that small enterprises contributed 18.9 % of the 1998 Gross Domestic Product (GDP) and 25.5 % of the non-agricultural GDP. Moreover, by 2002, SMEs employed 74.2% of the total persons engaged in employment.

The Sessional Paper No. 2 of 2005 on Development of small and micro enterprises highlights the major role played by SME in employment. According to the Economic Survey 2005, SME employed 78% of the total persons engaged in employment. This shows the importance this sector plays in the Kenyan economy.

According to the above session papers, substantial funds have been spent to implement government policies and programmes, and to build institutions specifically aimed at promoting the SME Sector since independence in 1963. The challenges considered critical to the development of the SME sector is the development of business management and entrepreneurial skills. Consequently, potential entrepreneurs enter the sector ill prepared to effectively contribute to its success, while the existing ones remain latent in their operations.

Forty-two percent of SME in Kenya mainly depend on the quality of their services and products as well as customer satisfaction as the main method of promotion of their goods and services (Republic of Kenya, 1999). It is therefore clear that the quality of goods and services is a major competitive factor for SME. The above survey pointed out that more than one third (34.1%) of the entrepreneurs had difficulties arising from market saturation or low demand for products.

Kenya Power and Lighting Company (KPLC), a monopoly infrastructure provider of electricity has 100% linkage with Electrical contractors. KPLC receives complaints regarding delay of electricity connections attributable to electrical contractors. Damage compensation claims arising from faulty electrical installations are also frequent (KPLC Records).

1.2 Need for Managerial Skills

In the literature, it is argued that, entrepreneurial managers need a sound foundation in what are considered traditional management skills (Timons and Spinelli (2005). The authors point out that one such skill is project management which entails organizing projects teams, setting project goals, defining project tasks, and monitoring task completion in the face of problems and cost/ quality constraints.

The three prime objectives of project management are to meet specified performance within cost and on schedule (Meredith and Mantel, 1989). Timely completion of projects is viewed as one way of enhancing competitiveness of business. To support this view, Stoner et al (2005), conclude that in today's volatile business environment, speed and response time are extremely important. A wonderful new product idea or a vision of a novel of service is meaningless unless it can be delivered to customers in a timely way. True, managers must analyze their decisions and carefully reflect on available information. This process of analysis is the backbone of effective decision making. Yet leaders must be action oriented .They must avoid the tendency to over evaluate decisions. Indeed, while they wait for more information and gain assurance that the risk is acceptable, a competitor may act.

Project Management is a well established discipline defining in considerable detail the tools and techniques required to define, plan and implement a project. However, while many researchers have addressed the issues surrounding the management of projects within large firms, there has not been a lot published to date about the management of projects in SME (Murphy, 2006).

1.3 The Business of Electrical Contractors

Electrical contractors are firms or individuals licensed by the Electricity Regulatory Board (ERB) to carry out wiring installations in buildings. However, characteristically of most SME, many of them are not licensed. For the purpose of this study both unlicensed and licensed, registered or unregistered persons involved in electrical projects are regarded as contractors.

A typical installation project involves project conceptualization stage where the contractor needs to develop very clear goals and objectives. The contractor needs to get plan of building, design the wiring, present the design to with the client and incorporate client's opinion. The contractor then prepares cost estimates. Having clarified the objectives, contractor can now estimate costs of labour, materials, contingencies and profit. The contractor then agrees with client on costs and payments schedule. Considering the expected delivery time, the work is broken down to tasks and a time schedule for the tasks is developed. The main tasks are piping, positioning of boxes, wiring, fittings and finally test and commissioning.

At the implementation stage, the resources are allocated for each of the tasks. This phase also entails monitoring the progress against the set targets and taking remedial action where deviations occur. The completion of the above tasks is frequently subject to completion of certain phases of the building, by the building contractor. It is also subject to connection of supply by the public utility KPLC. Therefore delayed connection by KPLC results in delays in some of payments due by the contractor.

From the foregoing, it is clear that Electrical Contractors are involved in a business which has all the characteristics of projects namely time, budget and quality constraints in addition to having risks, all which have to be managed for the successful delivery of the project outputs.

Statement of the Problem

Records from Kenya Power and Lighting (KPLC) indicated that only 680 contractors were registered in the country. It was quite clear that this small number could not cope with wiring the over 60,000 connections done annually by KPLC. The most likely scenario was that most of the electrical work done in premises was by unregistered contractors. Further, a lot of complaints by home owners and other institutions were about faulty wiring, flickering lights, or electrical shocks arising from water pipes. The KPLC records indicated that up to 20% of complaints regarding electricity interruptions were due to defective installations by contractors. This suggested that there was a quality problem in the implementation of projects by contractors.

Press reports frequently featured complaints by people complaining of delays in connecting their supply after payment to KPLC. A perusal of records from KPLC (Thika) revealed that about 300 jobs monthly could not be connected as a result of not fulfilling some obligations. One of those obligations was submission of completion certificates confirming that the premises were ready for electricity connection by KPLC.

One of the possible causes of the delay was due to the contractor not completing the works as a result of under quoting which would point to a costing or a scheduling problem. At times connection was delayed because applications for electricity supply, which were frequently duly completed and

submitted by contractors, were not submitted on time. This suggested a shortcoming in the planning process on the part of contractors.

This study was based on the premise that under quoting, lack of proper time scheduling inadequate quality control and lack of sufficient risk analysis were major contributory factors to project success in electrical contracting SME. However, there was no research that had studied this problem. The purpose of this study was to investigate the role that project management plays in the success of projects undertaken by SME in the electrical contracting sector.

1.4 Overall Objectives

The overall objective of this study was to investigate the role of project management in the success of projects undertaken by Entrepreneurs in Electrical Contracting SME.

1.4.1 Specific Objectives

(i) The extent to which electrical contractors apply project management skills in their business.
(ii) The most important aspects of project management necessary for successful implementation of projects in electrical contracting.
(iii) The factors limiting use of project management tools.
(iv) *T*he relationship between use of project management skills and project success.
(v) Project management issues that require further research.

1.5 Research Questions

(i) To what extent do electrical contractors use project management tools in their work?
(ii) What Project Management skills are critical to successful completion of electrical contractors?
(iii) What factors limit the use of Project Management skills by SME electrical contractors?
(iv) What is the relationship between use of project management skills and project success?
(v) What are the Project Management issues require further research?

1.6 Significance of the Study

This study would be of significance to the following categories of agents.

(i) Electrical contractors who may get sensitized about the knowledge of project management which if acquired can assist them improve their project success and business productivity.
(ii) The KPLC whose are currently lacking a more effective electrical contracting sector due to their lack of project management skills. Effective contractors will subsequently increase KPLC's customer base.
(iii) Government through Energy ministry whose objective of increasing national access to electricity from the current 15% to 40 % by 2010 depends also on productivity of electrical contracting sector, and labour ministry who is charged with promoting of SME as it will give them insights in identify sector specific project management skills and subsequent relevant training decisions.
(iv) The study will also be used by other researchers and scholars for relevant desk research and literature reviews.

1.7 Limitations of the Study

The major challenge faced during the research was accessibility to the contractors. Most of them were busy hence offered limited time to acquire the information required. This was however adequately addressed by use of persuasion.

1.8 Literature Review

The study adopted an exploratory approach in investigating the role of project management in the success of projects undertaken by entrepreneurs in electrical contracting SMEs. The dependent variable is project success while the independent variables include Application of Project management skills, Limitations in application of project management tools, Perception of its importance and other project management aspects. This chapter is outline as follows:

1.9 Project Management Overview

Meredith (2006) defines a project as a specific, finite task to be accomplished, whether large or small scale, or whether long or short term is not particularly relevant. However, project management is the discipline of organizing and managing resources in such a way that these resources deliver all the work required to complete a project within defined scope, time, and cost constraints (Harvey, 2005). A project is a temporary and one-time endeavor undertaken to create a unique product or service. This property of being a temporary and a one-time undertaking contrast with processes, or operations, which are permanent or semi-permanent ongoing functional work to create the same product or service over-and-over again. The management of these two systems is often very different and requires varying technical skills and philosophy, hence requiring the development of project management.

The challenge of project management is the optimized integration and allocation of the inputs needed to meet those pre-defined objectives. The project, therefore, is a carefully selected set of activities chosen to use resources (time, money, people, materials, energy, space, provisions, communication, quality, risk, etc.) to meet the pre-defined objectives. (http://en.wikipedia.org/wiki/Project_management)

1.10 Principles of Project Management

Project Management has existed, in theory, for centuries with its informal application by the Chinese and Egyptians with such feats as the Great Wall of China and the Pyramids. However, modern Project Management is a recent phenomenon gaining initial acceptance in the rapid development of the Information Technology industry, (Fox, 2004). Cicmil (1997: 390).

Project Management is an innovative process whose implementation is increasingly necessary in today's competitive market. Undertaking any project now involves overcoming many obstacles (Kerzner, 2001) that include project complexity, client special requirements, organizational restructuring and project risks. With a systematic process in place, such as Project Management, obstacles can be accounted for and actions or measures taken to either prevent or overcome them. Some of the many potential benefits project management provides as proposed by (Kerzner, 2001) include: Identification of functional responsibilities, ensuring that all activities are accounted for identification of time limits for scheduling, measurement of accomplishment against plans, early identification of problems and improved estimating capability. Essentially, project management is the planning, organizing, directing and controlling of an organization's resources to achieve a relatively short-term objective. Over its course, modern Project Management as a discipline has emerged and has been constantly remoulding itself to allow for expansion in its practice. A valuable conclusion was made by Crawford et al (2005:7) who carried out a study of the International Journal of Project Management and the Project Management Journal over the last ten years to try to uncover the trends in project management:

1.11 The Role of Project Management in Organizations

According to Meredith (1989) project management provides an organization with powerful tools that improves the organizations ability to plan, organize important and centre its activities and the ways it uses its people and resources. The author identifies intense competition amongst institution, both profit and non-profit as one of the societal forces that is fostered by the economic system.

This has put extreme pressure on business to make customized goods and services as quickly as possible. Meredith (1989) says that as a result of the need to avail goods and services more quickly, responses must come faster, decisions must be made sooner and results must occur more quickly. The author notes that information and knowledge are flowing explosively, but the allowable time to locate and use the approximate knowledge is decreasing.

The project manager is expected to integrate all aspects of the project, ensure that proper knowledge and resources are available when and where needed and above all ensure that the expected results are produced in a timely, cost effective manner. Meredith (1989) explains that the outcome of a project includes the product or services itself, the time at which the outcome is available and the cost entailed in achieving the outcome. For example the competition of a building on time and on budget is quite a different outcome from the competition of the same physical structure a year late or 20% over budget or both.

On the other hand Harvey (2005) views projects management not just as the steps required to complete a product but as a tool for systematically incorporating the voice of the customer, creating a disciplined way of prioritizing effort and resolving trade offs, working as concurrently on all aspects of the project and much more. The author notes that in the Toyota firm, 60% of the activities are pure waste, and that this waste can be removed by project management techniques.

1.12 Project Management and SME

According to Murphy (2006), one innovative step that can enhance the chances of progression in SME is the introduction of the process of the project management. The author observes that with SME contributing 99% of activities in the European Union (EU,) the SME's need to increase their competitiveness and quality to match competition and that project management techniques can be used to achieve this. Although intended for application in large organizations with complex systems that require such a process, Bacharini (1999), modern methods of project management can be adopted and altered to suit the needs of the small organizations.

Harvey (2005) supports the application of project management to work that is "similar to previous work in terms of either process followed, or the product delivered". This is described as "the job we did last time but with the following differences". This suggests that SME's involved in Electrical contracting do indeed qualify as businesses where application of project management can be beneficial

1.13 Use of Project Planning by Electrical Contractors

Different authors are in agreement about the planning process. (Murphy 2006, Meredith 2003, Harvey 2005). According to the authors, every project needs to identify what is to be done, how much it will cost and by when it will be completed. Project planning defines the project activities and end products that will be performed and describes how the activities will be accomplished. The purpose of project planning is to define each major task, estimate the time and resources required, and provide a framework for managements review and control.

Planning entails deciding in advance what a project will achieve, the steps of execution, assigning people and other resources to those steps and identifying when the steps will begin and stop .Activities include defining goals and objectives, assessing risks, estimation, budgeting ,allocating resources, defining tasks and building schedules. The Schedule is a key document that is based on project task sequence, recognizes task interdependencies and communicates to the project team

1.14 Inadequate Performance Controls by Electrical Contractors

Various authors, like Meredith (1985), Harvey, (2005) cite the importance of monitoring and control in project management. Control entails assessing how well project uses its plans and organization to achieve its goals and objectives. Activities include setting up change control, solving problems, tracking, monitoring, performing, contingency planning and re-planning Performance Control requires monitoring project performance and taking corrective action.

Project Monitoring requires reviewing the work schedule in order to answer the following questions: Is progress satisfactory? Is corrective action needed? And must we re-plan? It communicates project progress to team members and management. The review also addresses Management's needs and concerns through: documenting the following: A reminder of the project objectives: How well is the project doing? What actions are being taken to guide project? And are there any issues we should know about which affect the project's future?

1.15 Lack of Coordination Skills by Electrical Contractors

Coordination involves motivating people to perform satisfactorily on their job. Activities involved include delegation, communication and motivation. Effectiveness of coordination depends on the management style adopted by the project manager and its appropriateness to project being implemented.

1.16 Communication

Typical literary definitions of effective communications (Kerzner, 2001) include an exchange of information, an act or instance of transmitting information, a verbal or written message, a technique for expressing ideas effectively, or process by which meanings are exchanged between individuals through a common system of symbols.

According to Meredith *et al.,* (1985), communication skill is the most important skill required of a project manager. The importance of communication therefore cannot be overemphasized in managing p in SME projects. Evidently, there is a high failure rate of projects. There is evidence that poor or insufficient communication is one of the factors that contribute to the high failure rate of these projects. Effective communication is important in all the main phases of projects namely initiation, execution and closedown.

1.17 Quality in Goods and Services

Quality has been defined as the degree of excellence; the degree to which a product /service fits the purpose for which it was produced/delivered Quality is a near obsession for many companies. In fact, quality management is the expected way of operating for most business today. Quality management is nothing more than a company's unique approach for addressing quality. The foundation of quality management is a philosophy known as continuous improvement, which refers to a company's effort to provide steadily higher levels of quality through out all phases of its operation. This means each step in the production process is altered to make it better. This often results in more efficient and less costly ways of making a product. Continuous improvement also means that the products and services provided to customers are getting better all the time (Stoner et al, 2001).

1.18 Total Quality Management

Total quality management (TQM) 'as a management approach of an organization centered on quality, based on the participation of all its members and aiming at long-term success. This is achieved through customer satisfaction and benefits to all members of the organization and to society. In other words, TQM is a philosophy for managing an organization in a way, which enables it to meet stakeholder needs and expectations efficiency and effectively, without compromising ethical values' (ISO 8402, 19940).

The institute of Quality Assurance (IQA) considers TQM as a way of thinking about goals, organizations, processes and people to ensure that the right things are done right first time. This thought process can change attitude, behaviour and hence results for the better. From the opposite perspective; TQM is not a system, a tool or even a process, but an enabling philosophy supported by a series of systems, tools and processes are employed to achieve the various principles of TQM. In recent years, Moreover, TQM has also radically altered the way in which members of an organization work and to contribute to total performance. Today the most progressive organizations are embarking on the journey of transformation towards TQM, and this is coupled with the spread, from manufacturing to service sector and on to public services. It promotes the use of interdisciplinary teams of workers who must work cooperatively and collaboratively to achieve common objectives with the backing of management" (KEBS, 2005).

1.19 Conceptual Framework

The conceptual framework for this study was based on four independent variables namely application of project management skills, Limitations in application of project management tools, Perception of its importance and other project management aspects. The dependent variable are defined as those variables affected by the independent variables, which in this case is project success. It specifically zero in on project completion within schedule, budget, meeting technical specifications and results in customer satisfactions.. This relationship is summarized in the figure below.

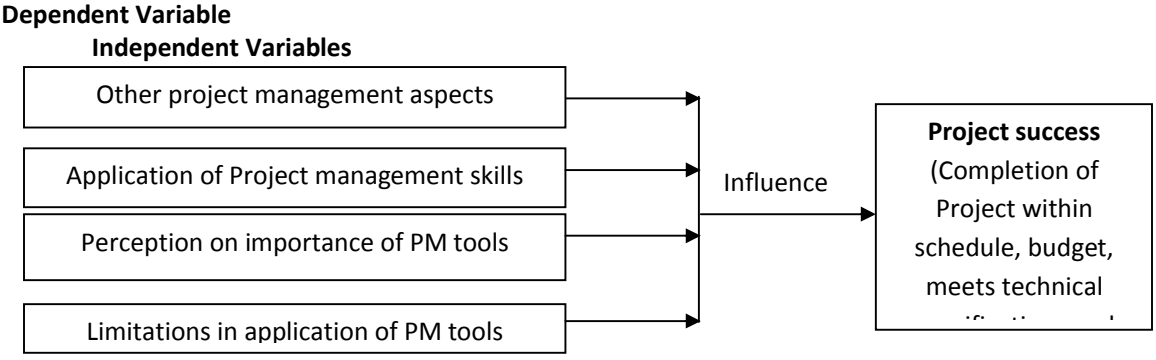


Figure 1: Conceptual Framework

2.0 Research Methodology

2.1 Introduction

In order to identify the most important factors necessary for project management in Small and Medium enterprises, the study adopted an exploratory approach. This chapter describes the research methods and gives highlights on population, sample, instrumentation and pilot testing and analysis of data in that order.

2.2 Population

The study focused on electrical contractors in Thika area. It included those registered with the ERB and those who are unregistered. A list of all contractors active in Thika area was sourced from Kenya Power and Lighting records and from the Association of Electrical contractors in Thika. The records indicated that there were 8 registered contractors operating in Thika. From the records of The Association of Electrical contractors in Thika, there were further estimated 30 unregistered contractors. The population was the 38 Electrical contractors operating within Thika Area.

2.3 Sample

In order to collect enough data and information, the study carried out a census of all the 38 known registered and unregistered contractors working in Thika Area. As this is a complete enumeration of all the items in the population, it was a census inquiry. The source list from where this was drawn had been prepared by the Association of Electrical Contractors, Thika. The Association keeps records of all the active contractors in the Area. Kothari (2004), emphasizes that where the universe is a small one, it is no use resorting to a sample survey. The list constitutes the universe.

2.4 Instruments

Primary data was collected using semi-structured questionnaire. This had the advantage of enumerators being able to interpret questions for any semi-literate respondents. The semi structured questionnaire also had the advantage of increasing the response rate. To reduce interviewer bias, honest and competent enumerators were used. This method helped realize other advantages associated with schedules, namely, flexibility in the questioning process, control of the interview situation, high response rate and fuller information (Nachmias *et al*., 2004).

The questionnaire was designed to assess application of Project Management tools, such as goal setting, management support, resource allocation, stakeholder consultation, planning, work organization, monitoring and control and risk management. Secondary data was obtained from existing reports from the Kenya Power and Lighting Company.

2.5 Pilot Testing

A pilot survey was done. The pilot testing was carried out on 5 contractors randomly picked from the population. This was used as a way to test the validity and reliability of semi-structured questionnaire since a pilot test is a replica and rehearsal of the main survey. The pilot testing helped in pointing out the weaknesses if any in the questionnaires. It was important in detecting them early in order to adjust the weak areas and get the required data and information, which is in conformity with research objectives and questions.

2. Data Analysis

Data was coded using a predetermined coding scheme following the rules of data coding of exhaustiveness and exclusiveness as stated in Kothari (2003). To improve reliability, edge coding was used. The Statistical Package for Social Science (SPSS) was used to analyze quantitative data. Qualitative analysis consisted of categorizing, tabulating and recombining evidences to address the research questions which were used as a unit of analysis. Quantitative analysis was done using descriptive statistics. These are concerned with the development of certain indices using raw data such as frequency counts, percentages and graphs to describe distributions, pie charts to show differences in frequencies and bar charts to display nominal or ordinal data (Cooper and Schindler, 1998). Pearson's correlation was used to establish the relationship between important variables.

3.0 Summary of the Findings

3.1 Respondents Profile

Most (47%) of the contractors were small income earners with a monthly turnover of between KShs 10,000 to KShs20, 000. Few made over KShs 20,000 with 22% making a turnover of KShs 30,000 to KShs50, 000. See figure 4.1 for details. The research also showed that most of the contractors were of the age of 21 to 30 years. A considerable decrease in number of contractors was noticed with an increase in age. This suggests that most of the electrical contractors are young. Concerning their knowledge about project management, 42% of the respondents said that project management is all about organizing the resources like time, labour and money in order to enable the work to run smoothly. The description they gave is close to the definitions given by various project management authors (Meredith, 1989; Harvey, 2005; and Baccarini 1999).

3.2 Level of Education and Training in Project Management

Majority (70%) of the contractors had at some point attended training on project management. These were mainly done in seminars and workshops (70%) with a few (23%) providing certificate courses while very few (7%) had undergone a Diploma course. The findings imply that the contractors are more trained on project management than it was expected. According to Murphy (2006), one innovative step that can enhance the chances of progression in SME is the introduction of the process of the project management.

This suggests that there is a likely significant growth in the SME electrical contracting in future. The research indicated that most contractors valued the knowledge of PM and regarded the training they had received as vital for their businesses which agrees with the publication in the International Journal of Project Management 24, 2006 where over 80% of managers in the construction industry rated most of the project management topics as relevant to the industry.

3.3 Application of Project Management (PM) in Electrical Contracting

3.3.1 Steps in Electrical Contracting Project Management

The research showed that most contractors first surveyed the work and planned for it before the actual implementation of the project. This was usually accompanied by the writing of a quotation and duty assignment by the responsible persons. However, some contractors considered writing quotation to be the second step in project management. This was accompanied by the commencing of the work, monitoring of the progress, agreement on payment, down payments and settling of balances or payments. This was accompanied by the purchase of material.

Most respondents considered the purchase of material to be their third step in a project. This was followed by the start of the actual work and agreement in payment. Testing, paying of down payment and the final completion of the work were some of the other actions considered to be part of the third step. The research showed that electrical project management is a long process made of several steps. These are shown in the table below as suggested by the respondents and the actions thought to be part of each step in the implementation of the project.

3.4 Whether SME Electrical Contractors Use Some Key PM Skills

All respondents said they normally have a clear work plan. Majority (76%) of the respondents allocate resources before starting work. The following are their reasons for doing so.

3.5 Risks faced and Risk Management Techniques Used

Majority (82%) of the contractors confided that they experienced price increment in the course of a project. These were mainly attributed to the client delay to make a down payment or give a go ahead to the implementation of the project. In such cases, majority (74%) of the contractors experienced their client's changing their minds on specifications after the project has started. The following actions were taken to solve such problems. Incase of a sudden unavailability of materials alternative sourcing from other available supplies are done while the few (16%) who experienced labour unavailability while still in a project resorted to managing the project to operate within specified time and enhancing workers loyalty.

3.6 Extent of Applying Various Aspects of Project Management

Of all these aspects, the most practiced was development of a good budget and schedule. Monitoring of the progress made was highly practiced taking into consideration any corrective actions to be taken. Compared to the importance attached to various project management aspects by the electrical contractors, it appears that most contractors do not practice various project management aspects as much as they think they are important. This agrees with research that was published in the International Journal of Project Management 24, 2006 where over 80% of managers in the construction industry rated most of the project management topics as relevant to the industry.

3.7 Importance of PM Skills in Successful Electrical Contracting

Most contractors considered the level of customer satisfaction to be the most ideal way of assessing the success of a project. The assessment criteria of project success being mainly guided by customer satisfaction agrees with research that was published in the International Journal of Project

Management 24, 2006 where 93% of managers in the construction industry rated stakeholder management as potential new topic for PM training.
On the other hand, a good quotation and budget and time management/scheduling were considered the most crucial skills in PM, which agrees with research that was published in the International Journal of Project Management 24, 2006 where 95% of managers in the construction industry rated budgeting and cost management as relevant to the industry which was above the average appreciation across all industries.

3.8 Factors Limiting Use of PM in Electrical Contracting

The study showed that the use of unqualified workforce and inadequate funds are the major contributors to the laxity in use of PM. Lack of honesty leading to mistrust by clients and employees has also contributed to this scenario. However, the major challenges faced by the contractors when dealing with customers was failure by the client to pay or delay to pay.

3.9 Relationship between Customer Satisfaction and Project Management Aspects

The importance and practice of aspects under study were fitted into a correlation matrix against the level of satisfaction. In terms of practice, the following aspects were found to have a positive correlation with the satisfaction derived: Project definition; Strategy selection; Writing of operational manual; Delivery to client and Training of client personnel. However, only *project definition* had a positive correlation at 0.05 significance level while *training of client personnel* had a positive correlation at same significance level.

In terms of importance, the following had a positive correlation with the level of satisfaction: Project definition; Strategy selection; Schedule development; Budget development; Training of new team members; Delivery to client; Disposal of surplus material; Carrying out of final audit; Complete project report and Review project management. However, Only *Project definition* and *disposal of surplus material* had positive correlation at 0.05% significance level while *Strategy selection* and *schedule development* had a positive correlation at 0.01 significance level.

This implied that for any organization to achieve the desired level of satisfaction from their client, it was necessary that all the aspects considered being importance be practiced keenly and special attention given to them. Aspects such as *schedule development*, *complete project report*, *carrying out final audit*, *budget development* etc. should be accorded the same level of practice as the other important aspects.

It was noted that all significant correlation were positive. This means that PM skills are useful in enhancing customer satisfaction. In some cases, like strategy selection and schedule development perception of some PM aspects as important had a significant positive relationship with customer satisfaction. Simple appreciation of PM may therefore enhance customer satisfaction. This can drive intuitive actions that can enhance project success and therefore satisfy the customer.

4.0 Conclusions

The conclusions of the research are based on the responses given in each of the four factors that have been analyzed based on the data received .The research therefore concluded that application of project management skills was a major factor in determining the success of the project. If well practiced, this can greatly increase the success and turnover of the contractor. The research further found out that the contractors who practiced PM skills had higher customer satisfaction than their counterparts.

Nevertheless, it also emerged quite clearly that while many contractors put a high premium on project management skills, relatively few used these skills in their enterprises. Moreover, except

perhaps for lack of sufficient funds as reason for not using project management tools, reasons provided for not making more use of these skills do not appear to agree with the project management skills considered crucial by the contractors namely drawing up quotations, budgeting and work scheduling.

The fact that some contractors who perceive certain aspects of project management as important do not practice the same aspects implies a high likelihood that they use intuition and improvisation in managing projects. This may be driven by the need to overcome the limits of rationality in loosely structured situations. Further there was a significant positive relationship between those who attached high importance to some aspects of PM and customer satisfaction.

Recommendations

The recommendations derived from the study were as follows:

(I) There is a need for Thika Association of Electrical Contractors to closely study the methods used in addressing various obstacles by the contractors and the most effective ones should be applied depending on the prevailing situation. These would greatly assist in keeping the clients satisfied and therefore avoid any loss of clients.

(II) The government, ERB (Electricity Regulation Board) and KPLC should provide training to SME contractors on stakeholder management as most challenges faced were related with this aspect.

(III) KPLC should create more public awareness on the quality of electrical wiring This would help reduce conflict between them and the electrical contractors through increased understanding.

(IV) ERB should recognize that majority of electrical contractors use alliance with registered contractors and therefore customize licensing requirements for SMEs. The licensing process should also be made more efficient to reduce red tape.

(V) Entrepreneurs should seize the opportunity provided by unavailability of materials in Thika and invest in well stocked electrical hardware outlets.

(VI) More research should be carried out in the field to determine other challenges in project management and ways of combating and changing them in to electrical contracting resources.

References

Baccarini, D. (1999). History of Project Management. School of Architecture, Construction and Planning, Curtin University of Technology.

Cicmil, (1997). *Critical factors of effective project management*. *The TQM Magazine*,**9**, PP 390-393.
Crawford, L., Pollack, J. et al. (2005). Uncovering the trends in project management: Journal emphases over the last 10 years. International Journal of Project Management.

Fry, L. F., Stoner, R. C. and Hattwick, E. R. (2001). Business, Integrative Approach (2nd edition) Mc. Graw- Hill Higher Education.

International Project Management Association (2006. Research Updating the APM Body of Knowledge 4th edition, *International Journal of Project Management*, Vol **24**(6), pp 493-505.

Kenya Bureau of Statistics (2005). Seminar on Implementation of ISO 9000 Standards. KEBS Training and advisory services 2005.

Kerzner, H. (2001). Project Management - A Systems Approach to Planning, Scheduling and Controlling.

Kirytopoulous, K., Leopolous V. and Malandakris C. (1999). A Powerful tool for improving efficiency of project oriented SMES.

Kothari, C. R. (2004). Research Methodology. Methods and Techniques (2nd Edition) New Age International Publishers.

Maylor, H. (2005). Project Management (3rd Edition) Ashford Color Press Ltd, Gosport\
Meredith R. Jack, Mantel J. Samuel Jr. (1989) Project Management. A Managerial Approach (2nd Edition) John Wiley and Sons, Inc.

Murphy, A. (2006). project Management and Techniques in High-Tech SMEs in Ireland \Nachmias David and Frankfort-Nachmias Chava (2004). Research Methods in the social sciences (5th Edition) Replica Press Printing Ltd.

Perreault, D. William Jr. and McCarthy Jerome E. (2003). Essentials of Marketing (9th Edition). McGraw-Hill/Irwin.

Republic of Kenya, Central Bureau of statistics, international center for Economic growth (ICEG), and K-Rep holdings ltd. (1999) *National Micro and Small Enterprise Baseline Survey 1999*. Survey results, Nairobi. Central Bureau of Statistics International Center for Economic Growth, K-Rep Holdings Ltd.

Republic of Kenya (2004) *Energy* (sessional Paper No.4) Nairobi: Government Printer
Republic of Kenya (1992) Small Enterprise and Jua Kali and Development *in Kenya* (Sessional Paper No. 2) Nairobi: Government Printers.
Republic of Kenya (2005) Development of Micro and small enterprise for wealth *and employment creation for poverty reduction* (sessional Paper No. 2) Nairobi: Government Printer.

White, D. and J. Fortune (2002). Current Practice in Project Management *an* empirical study. *International Journal of Project Management*, **20**, pp 1-11.

H. M. Bwisa
Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
bwihem@gmail.com

Abstract
Many African universities offer entrepreneurship education aimed at producing self-employable graduates to create employment. Kenya pioneered on the continent in starting a master's degree in entrepreneurship in the 1990s at its Jomo Kenyatta University of Agriculture and Technology. Many other countries on the continent have introduced entrepreneurship education/training in one form or another at one level of education or another. However not many of entrepreneurship graduates are self-employed. Has this to do with the method of preparing the students? This author conducted research in Kenya to attempt an answer. The research produced findings which can be generalized and replicated on the continent. This paper presents the research findings which are used to give, among others, the following recommendations for Africa:

(i) Employ effective entrepreneurship delivery and assessment methods
(ii) Develop effective entrepreneurship educators
(iii) Integrate entrepreneurs in curricula design and delivery
(iv) Establish university business incubators

1.0 Introduction

Developing as well as developed countries acknowledge the role and importance of Small and Medium Enterprises (SMEs) in generating employment, stimulating growth and creating social cohesion. Interest in SMEs is further enhanced in the face of globalization, which is increasingly becoming an influential force in world trade. Because of their flexibility and quick adaptability to change, SMEs are viewed as instruments capable of responding to globalization (ECA, 2000). A 2004 OECD conference revealed that SMEs contribute to over 55% of GDP and over 65% of total employment in high-income countries; account for over 60% of GDP and over 70% of total employment in low-income countries and contribute over 95% of total employment and about 70% of GDP in middle-income countries (OECD, 2004).

In 2005 a FAO/WHO (Food and Agriculture Organization and World Health Organization) conference was held in Harare, Zimbabwe. The conference stressed the importance of SMEs to the economies of the region and recognized the constraints facing SMEs in producing safe and high quality food, as well as the need to generate and implement practical solutions to address these problems.

Despite them being recognised, the mortality rate of SMEs in Africa remains high. In Kenya, for example the SME sector contributed over 50 percent of new jobs created in 2005 but despite their significance, SMEs, "are faced with the threat of failure with past statistics indicating that three out five fail within the first few months" (Bowen, et al. 2009).

Two areas that have generated interest in terms of trying to unravel the high mortality rate of SMEs are the entrepreneurship skills and entrepreneurial culture areas. In Africa today the question – can entrepreneurship be taught is no longer valid. The valid questions are – how should entrepreneurship be taught and what should be taught?

In recognition of the importance of entrepreneurship education for SME development, many African countries have introduced entrepreneurship education. Kabogo, J. D., (2008) studied the status of entrepreneurship education in colleges and universities of sub-Saharan Africa. 106 institutions in 36 countries were earmarked for study but 66 were actually studied. 86% of the 66 institutions studied, i.e., 57 in number have at least a course in entrepreneurship. The continent's prominent university leadership continues to stress the importance of entrepreneurship education. Thus Nigeria's Vanguard of 24th March 2010 carried an article in which Nigeria's Novena University Vice Chancellor stressed the need for entrepreneurship education as the only way to achieve the country's vision 20-2020. He referred to the fact that India and China are now considered emerging economies because of entrepreneurship.

African students themselves are now demanding for entrepreneurship education. Thus the Citizen paper of Dar es Salaam, Tanzania in its 14th August 2010 article entitled "Tanzania: Introduce Entrepreneurship Education in Schools" reported the Tanzanian youth urging the government to introduce entrepreneurship education in all levels of education to solve unemployment problems.

Clearly therefore, Africa is producing entrepreneurship cadre to steer the SME sector. Is the cadre doing what it is expected of? That is the question.

In sub-Saharan Africa entrepreneurship education at Masters and PhD levels is said to have been first introduced in Kenya in the 1990s. In 1990 the Government of Kenya, in collaboration with International Labour Organization (ILO), United Nations Development Program (UNDP) and University of Illinois of the USA started the first, known to this author, Masters and PhD in Entrepreneurship Degrees on the sub-continent. This was a two year University of Illinois project housed at a technical college in Kenya. When in 1992 the project came to an end the Jomo Kenyatta

University of Agriculture and Technology (JKUAT) institutionalized it. This author chaired the university committee that institutionalized the programme.

It must quickly be mentioned that JKUAT institutionalized the programme before she had a critical minimum of educators in the subject. Professors from the University of Illinois were therefore understudied by their JKUAT counter-parts to be able to conduct entrepreneurship education. Having finished their mission of inducting JKUAT professors, two of the University of Illinois professors (Robert Nelson and Scott Johnson) in their article, "entrepreneurship education as a strategic approach to education growth in Kenya" published in the Journal of Industrial Teacher Education Vol. 35 No. 1 of 1997 made several recommendations in regard to entrepreneurship education in Kenya. They included, to expose trainees to successful small enterprises; to enable students practice entrepreneurial attributes; to enable students familiarize with entrepreneurial and managerial tasks; to enable students utilize small enterprises, family acquaintances and community contacts to assist them implement business opportunities.

The unwritten message by these recommendations was that entrepreneurship education delivery methods should achieve the said goals. The question becomes - Have delivery methods at Kenyan universities achieved this?

Motivated by the poor performance and high mortality rate among South Africa's SMEs Kunene, T. R. (2008) undertook a PhD study of a critical analysis of entrepreneurial and business skills in SMEs of South Africa.. Her results indicate that there is a need to impart key entrepreneurial skills to SME operators.

In terms of entrepreneurial culture, Volker Wild (1997) published a book on the development of private enterprise within the indigenous population in Zimbabwe. The primary aim of the book is to show that the lack of economic success of African business people in Zimbabwe is due to the fact that their economic goals are not rooted in profit for profit's sake, which, he argues, is fundamental to capitalist enterprise. The author maintains that in Africa, culture, social and familial obligations, and the desire for social status are prime motives for economic success. Once such objectives have been achieved, the push for increased profits wanes. There may be debatable aspects of the book but the fact that it introduces the issue of entrepreneurial culture is important for this paper.

One web definition of culture is "a collective programming of the mind that distinguishes the members of one group or category of people from another" (wordnetweb.princeton.edu/perl/webwn). Based on this definition and using innovation as the key characteristic of entrepreneurship as given by two gurus of entrepreneurship – Joseph Schumpeter and Peter Drucker – this author is tempted to offer a definition of entrepreneurial culture as, "a behaviour and/or spirit which leads to the innovative practice of identifying opportunities and acting on them in a productive and value adding way". The difference between entrepreneurial and business culture may be blurred but can be summed up in the phrase, "entrepreneurs are business people but not all business people are entrepreneurs". Entrepreneurs are therefore a special breed of business people and entrepreneurship a special business activity/practice.

Writing on Evan Carmichael website (www.evancarmichael.com), Waswa Balunywa of Makerere University Business School in Kampala, Uganda argues that it is possible that in Uganda, in the study of business, especially small business, there has been no attention to the subject of culture and its impact on business success. "We appear to take it for granted that the concept of business, which is a cultural pattern in different societies, is understood the same way everywhere. Discussing entrepreneurship we conclude that successful entrepreneurship entails certain behavioural patterns.

That behaviour is shaped in a cultural setting. We also appear to take it for granted that the concept of profit, the end result of a business activity, as a common meaning in different cultures).

This argument cannot be said to be farfetched. The influence of culture on entrepreneurship has been of continued scholarly interest for over a number of decades. Researchers have explored the effect of national, regional, and organizational cultures on wealth creation through new venture creation, innovation, and risk taking. Using data from multiple countries and applying diverse research methods, organizational scholars have explored the relationship between cultural variables and entrepreneurial behavior and outcomes. One such a scholar is G. Hofstede.

In some of his major studies, Hofstede, G., (1980, 2001) describes the different cultures in different countries and comes up with what he calls cultural dimensions which give some explanation as to the behaviour of people in economic activities. Hofstede introduces four dimensions which he calls a number of phenomena in a society which occur in combination. These include power distance, individualism versus collectivism, masculinity versus femininity, and uncertainty avoidance. It is not the objective of this paper to delve into these dimensions.

1.1 Statement of the Problem

The foundation of the research whose findings this paper carries was a general observation that despite entrepreneurship education having been in existence for two decades in Kenya, many of its graduates cannot be said to be productively self-employed. The implication is that an entrepreneurial culture may not have been effectively inculcated. The research question which constituted the research problem became – has the process of producing entrepreneurship graduates effectively inculcated an entrepreneurial culture? In addressing this research problem the following:

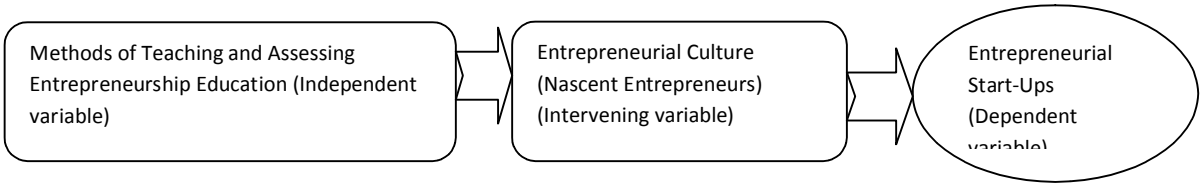


Figure 1: relation between teaching and start-ups

1.2 Objectives of the Study

This study had as its key objective the investigation of the degree of inculcation of entrepreneurial culture into the students of entrepreneurship. Specifically the study sought to solicit the views of the students (as customers) on the delivery and assessment of entrepreneurship education.

1.3 Literature Review

1.3.1 Definition of Entrepreneurship

Literature has no one universally accepted definition of entrepreneurship. Nevertheless if one considers that the key reason for introducing entrepreneurship education was to assist graduates venture into self-employment as opposed to looking for wage employment then one starts to see that entrepreneurship is largely about starting a growth oriented (small) business. Entrepreneurship is therefore largely about small businesses. The term intrapreneurship or corporate entrepreneurship has been coined to represent entrepreneurship that goes on in large scale enterprises. There are at least three key differences between entrepreneurs and intrapreneurs anchored on factor of production, ownership and risk taking/bearing bases. One – for participation in the process of production entrepreneurs earn profits while intrapreneurs earn wages. The two are therefore different factors of production. Two- entrepreneurs are by definition owner managers

while intrapreneurs are employed managers. Three – entrepreneurs take and also bear business risk, intrapreneurs as employed managers take but may not necessarily bear the risk.

Entrepreneurship is, therefore, a (vital) process of stimulating economic growth and employment opportunities by accelerating sustainable business start-ups in all societies. This is particularly true in Africa, where successful growth-oriented small businesses are the primary engines of job creation and poverty reduction. These successful small businesses are started by entrepreneurs.

Despite lack of consensus on the definition of an entrepreneur scrutiny of many of the variations of the definition tends to bring out some commonalities. The aspects of innovation, creativity and value addition are either explicit or implicit in most definitions. Entrepreneurs are therefore innovative and creative individuals who create value to society. Some are born but many are made through the process of entrepreneurship education and training.

When taught entrepreneurship is the process by which new knowledge is converted to sustainable value, and that usually involves the creation of a business to do it. It is however not accurate to state that all business owners are entrepreneurs. Indeed all entrepreneurs may be business people but not all business people are entrepreneurs. This then ushers in the next question – what is entrepreneurship education?

1.4 Entrepreneurship Education

Literature has a range of definitions of entrepreneurship education, for instance as for enterprise, in enterprise and about enterprise (Henry and Hill, 1999). The main objective of education about enterprise is to increase the number of people with theoretical knowledge about starting and running an enterprise. Education for enterprise aims at preparing people for a career in self employment. It encourages and gives practical skills for setting up an enterprise. Education in enterprise takes a management approach for established enterprises: how they can grow and develop.

Reading between the lines of the aforesaid one may look at entrepreneurship education as the process of providing individuals with the concepts, creativity and skills to recognize opportunities that others have overlooked and to have the insight, self-esteem and knowledge to act where others have hesitated. Entrepreneurship education is about promoting change in attitudes to 'increase the number of students who view 'business start-up' as a viable career option' (Black, 2003). To succeed in this, entrepreneurship education must be concerned with learning and facilitating for entrepreneurship, not about it (Laukkanen, 2000; Cooper *et al*., 2004). 'The entrepreneurship educational system has to be oriented towards "doing" more than "thinking". Knowledge has to be converted into solutions that benefit customers in the market place' (Formica, 2002). The learning must be personal, practical and experiential through discovery (Dana, 1993; Gorman, 1997; Fayolle, 2001; Rae and Carswell, 2001; Bird, 2002-2003). Entrepreneurship education is a constructivist-based education (Ehrste´n and Kjellman, 2001).

The next logical question to pose is: how should entrepreneurship be taught?

1.5 How to Teach Entrepreneurship: Best Practices

The term "best practices" may be debatable. It is therefore used here with caution to imply what many scholars put premium on in terms of entrepreneurship teaching methods and methodologies. A popular internet anecdote about entrepreneurship compares teaching entrepreneurship without the experiential process (and without a business incubator – this author) to teaching someone to swim without a pool. The fundamentals about swimming can be taught but the individual will not really know what it is like to swim until the person dives into the pool and begins to swim. If one has

only been taught on land, then they will not likely have much confidence in their attempt to swim. Similarly, many students of entrepreneurship are entering their careers with only the fundamentals that were taught on "dry land."

To this anecdote one can add the 450 BC Confucian philosophy of: “Tell me and I will forget; show me and I may remember; involve me and I will understand.”

Rasmussen, E. A. and Sorheim, R. (2006) argue that entrepreneurship education has traditionally focused on teaching individuals, but many initiatives are increasingly becoming more action-oriented, emphasizing learning by doing. In their paper they present a number of action-based activities at five Swedish universities. The cases show that entrepreneurship education focuses less on teaching individuals in a classroom setting and more on learning-by-doing activities in a group setting and a network context.

One of the key conclusions reached at a European Commission conference (2006) was to embrace experiential learning. “In terms of delivery, a greater emphasis is needed on experiential and action learning. There are numerous pedagogies which can be utilized including case studies, team projects, and activities with entrepreneurs.

Mueller *et al*., (2006) compared entrepreneurship action learning outcomes for under-graduate students in Germany, Singapore, China, Korea, New Zealand, United States and Australia. In their conclusion they wrote, “We have investigated an action-learning based entrepreneurship program in seven countries on three continents, which attempts to give students the opportunity to apply their academic learning in a practical environment. These students have grown up with different cultural norms governing their rules of interaction and with different economic systems favouring/disfavouring free market enterprise. It is therefore remarkable for these participants to uniformly and consistently report outcomes which propel their learning ahead of those who do not engage in action learning events like these.

The message we get is that entrepreneurship is best taught via experiential learning but what actually is experiential learning?

1.6 Experiential Learning

Kolb (1984) described learning as "the process whereby knowledge is created through the transformation of experience." In other words experience is the source of learning and development. According to Kolb learning is a four stage cycle process. It occurs when students (1) engage in some activity, (2) reflect upon the activity, (3) derive insight from the analysis, and (4) incorporate the result through a change in understanding. This is experiential learning.

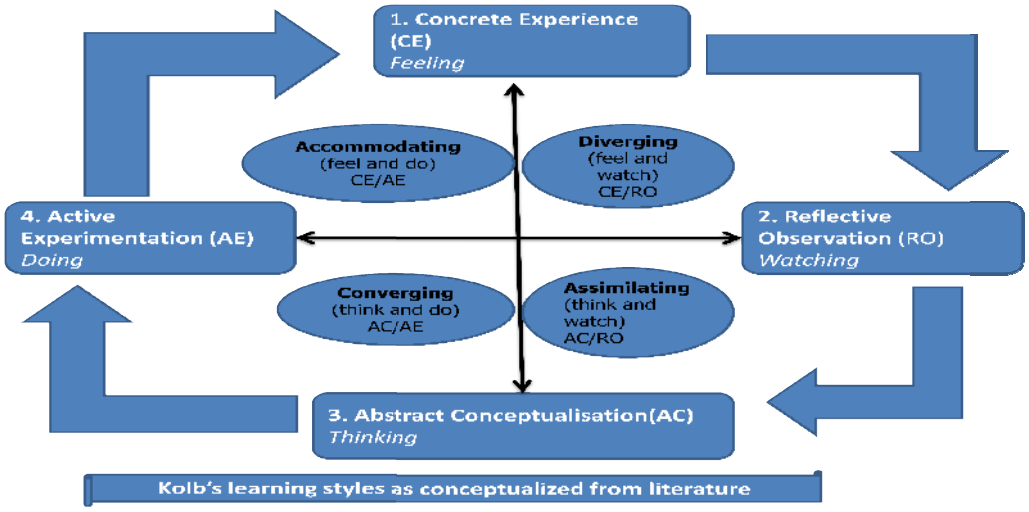


Figure 2: Kolb's four-stage experiential learning cycle

In Figure 2, diverging (concrete, reflective) - Emphasizes the innovative and imaginative approach to doing things. The learner views concrete situations from many perspectives and adapts by observation rather than by action. Assimilating (abstract, reflective) - Pulls a number of different observations and thoughts into an integrated whole. Converging (abstract, active)- Emphasizes the practical application of ideas and solving problems. Accommodating (concrete, active) - Uses trial and error rather than thought and reflection.The feeling, watching, thinking and doing reflected in Kolb's model remind us of the already cited Confucian philosophy of "I hear and I forget; I see and I remember; I do and I understand."

Experiential learning is active learning or learning by doing in which students apply their theoretical, classroom knowledge through "real world" experience and application. The notion of active learning suggests that students must do more than simply receive information and substantive material via the lecture method. Students must also engage and participate in activities and tasks that enhance comprehension, understanding, and knowledge. Active learning involves putting students in situations, which compel them to read, speak, listen, think deeply, and write. It can be argued that that while well delivered lectures are valuable and are not uncommon, often times the thinking required while attending a lecture is low level comprehension that goes from the ear to the writing hand and leaves the mind untouched.

"Learning is not a spectator sport. Students do not learn much just by sitting in class listening to teachers, memorizing repackaged assignments, and spitting out answers. They must talk about what they are learning, write about it, relate it to past experiences, and apply it to their daily lives. They must make what they learn part of themselves." (Chickering and Gamson, 1987).

Even without exhausting literature on how to teach entrepreneurship it appears that premium is put on active, learner centred, andragogical learning methods which we summarize as experiential methods. . The experiential approach assists the student to understand the environment within which business actually operates hence match classroom teachings with specific cultural set-ups. It also enhances knowledge retention by the learner.

1.7 Knowledge Retention

Edgar Dale (April 27, 1900 – March 8, 1985) a U.S educationist researched and developed the famous cone of experience. The cone demonstrates that retention of what we learn is higher when

active methods of learning are used than when passive methods are used. This is illustrated by the cone of learning developed by Edgar dale.

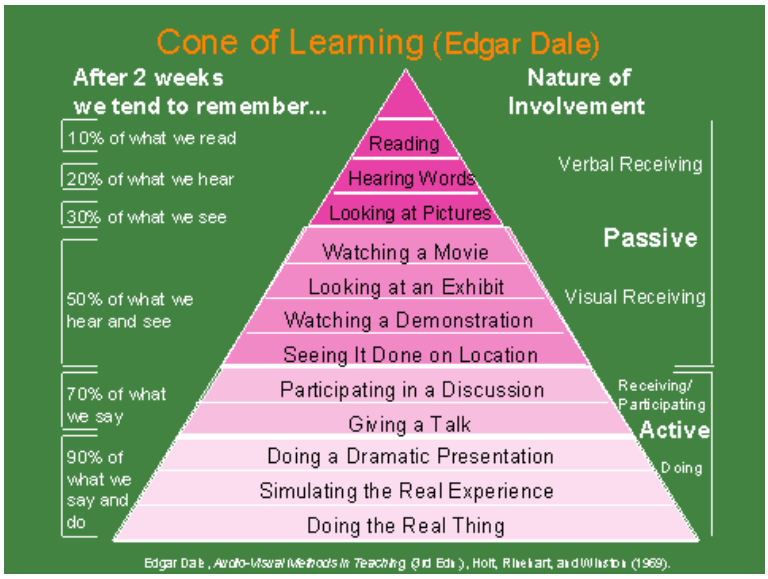


Figure 3: Edgar Dale's cone of learning

1.8 Methods of Assessment

Methods of assessment are known to be the means used to assess student learning--they are the educational practices we engage in to see if students are learning what we say they are learning.

Learning is not just about facts. It is also about appropriation of ideas, attitudes, values, and so on. Professor Benjamin Bloom of Chicago University and co-workers that met from 1948 to 1953 sorted out three domains or realms where learning or appropriation takes place. They are:

(i) Cognitive: Thinking, getting, evaluating and synthesizing information.
(ii) Affective: Feelings, preferences, values
(iii) Psychomotor: Physical and perceptual activities and skills.

The cognitive learning domain consists of acquiring intellectual skills. This domain addresses how individuals think; their intellectual capabilities, level of development and preferred thinking styles. The common method of assessment of the cognitive domain is the summative end of term timed written examination. The affective learning domain consists mainly of acquiring feelings. Very often insight rises atop of feelings. Dreams may be interpreted and understood in such a light, for example. Thus feeling may feed insights. Many renowned scientists and artists have had massive inspiration from their dreams. "Gentlemen, let's learn to dream," Albert Einstein is said to have expressed himself.

The psychomotor learning is a domain of skills expression. But what I do (with skill), I master [From the Chinese sayings]. One anonymous scholar wrote "Learning is pleasurable but doing is the height of enjoyment. Interestingly, manual skills may be the crown of achievements that cognitive skills lead into. And once hard-won dexterity or manual ability is learnt, it is often automated, like learning to swim, ride bikes. End of term timed written examinations are incapable of effectively assessing the affective and psychomotor domains. Formative assessment via presentations and projects (both individual and group) are known to better assess these domains.

The second edition of student learning assessment: options and resources published by the Middle States Commission on Higher Education in USA lists up to 12 examples of direct measures of student learning as:

(i) Course and homework assignments.
(ii) Examinations and quizzes.
(iii) Standardized tests.
(iv) Term papers and reports.
(v) Observations of field work, internship.
(vi) Performance, service learning, or clinical experiences.
(vii) Research projects.
(viii) Class discussion participation.
(ix) Case study analysis.
(x) Rubric (a criterion-based rating scale) scores for writing, oral presentations, and performances.
(xi) Artistic performances and products.
(xii) Grades that are based on explicit criteria related.

Traditionally, a majority of educators are said to consider the first four as the primary means for assessing student learning. This may be because many educators teach about not for. Entrepreneurship learning is not complete if it is not taught less about and more for.

1.9 Conceptual Framework

The covered literature makes possible a conceptualization that entrepreneurship is a process that starts with awareness creation among students. This awareness creates nascent entrepreneurs (those willing to start businesses). They eventually start and grow the businesses. The type of education and methods of its delivery (including student assessment) may stress different aspects at different stages.

In his internet presentation, "Facilitating Entrepreneurship" Alan Barefield (http://srdc.msstate.edu/presentation_archive/2003) proposes a seven stage entrepreneurship facilitation process. Below we borrow from it to conceptualize entrepreneurship learning approaches/methods.

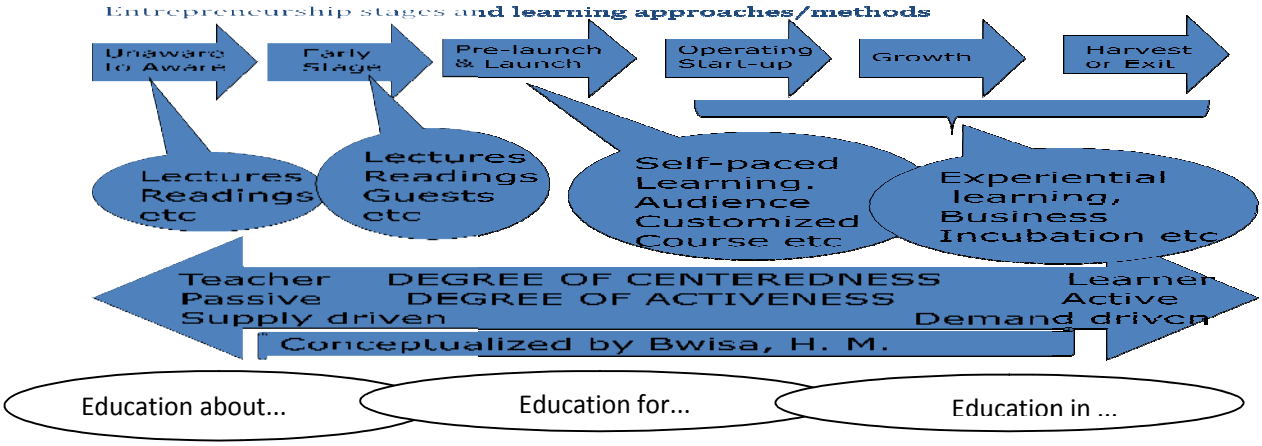


Figure 4: entrepreneurship learning approaches

2.0 Methodology

Kenyan universities teaching entrepreneurship in one form or another at one level or another were traversed with questionnaires and interview guides. Four sets of questionnaires were administered. The two main categories of respondents were the finalist students of entrepreneurship and those

who had already graduated. For completeness lecturers of entrepreneurship and heads of departments (as administrators) were also covered.

The choice of students as the unit of analysis was guided by the increasing business and entrepreneurship prudence of putting the customer first. In 1776 in *The Wealth of Nations*, Adam Smith wrote that the needs of producers should be considered only with regard to meeting the needs of consumers. This "customer first" philosophy is consistent with the business (read entrepreneurship) marketing concept whose philosophy is that firms should analyze the needs of their customers and then make decisions to satisfy those needs, better than the competition. Total quality management gurus have also stressed the customer first approach.

3.0 Findings

3.1 Methods of Delivery

Table 1 shows that a majority of lecturers at Kenyan universities use lectures, essays, readings and handouts in their delivery. The dominance of passive methods of teaching entrepreneurship is apparent. At some universities delivery methods such as group projects, local case studies, guest speakers, entrepreneur interviews, role playing, business plans, workshops and seminars were never used as delivery methods.

Table 1: Reported methods of delivery and their frequency of use

	Usage Of Method In Universities					
	Frequently		*Rarely*		*Never*	
Teaching Method	N	%	n	%	n	%
Lectures	33	97.1	1	2.9	-	-
Individual Projects	14	46.7	16	53.3	-	-
Group Projects	12	37.5	11	34.4	9	28.1
Local case studies	4	12.5	16	50.0	11	34.4
Video cases			4	12.9	27	87.1
Guest speakers	4	13.3	12	40.0	14	46.7
Entrepreneur interviews	5	16.7	10	29.4	15	44.1
Role-playing	5	16.7	7	23.3	18	60.0
Students' Business plan	14	43.8	15	46.9	3	9.4
Oral Presentations	15	44.1	10	29.4	9	26.5
Essays	10	29.4	11	35.5	10	32.3
Readings	11	36.7	14	46.7	5	14.7
Seminars/workshop	7	22.6	9	29.0	15	48.4
Handout materials	16	48.5	12	36.4	5	15.2

3.2 Methods of Assessment

Table 2 shows that written examinations are preferred by lecturers to methods such as projects.

Table 2: Reported methods of assessment

Method	*100% Usage*	*Up To 50% Usage*	*1 – 10% Usage*
Continuous assessment tests and end of semester sit-in written examinations	YES		
Group presentations		YES	

End of semester individual projects			YES

3.3 Opinion on Methods of Delivery

Table 3 indicates what methods of delivery the students of entrepreneurship thought were most beneficial. The majority of students thought they benefited most via non-lecture presentations such as PowerPoint presentations (PP) - 81% and group work - 81%. Students thought they learned the least via lectures (41%) and chalk and board (19%). Lecture methods received the highest disagreement rate when students were asked about how delivery methods helped them to learn.

Table 3: Opinion on method of delivery

The following methods help (helped) in my ability to learn i.e. my ability to learn course material increases (increased) in classes that instructors use(d) the following technologies/methods:

METHOD	STRONGLY AGREE	AGREE	UNDECIDED	DISAGREE	STRONGLY DISAGREE	BLANK	TOTAL
CHALK AND BLACKBOARD (WHITEBOARD)	6 (22%)	15 (56%)	1 (3%)	5 (19%)	0 (0%)	0 (0%)	27 (100%)
OVERHEAD PROJECTOR	12 (45%)	7 (26%)	3 (11%)	2 (7%)	0 (0%)	3 (11%)	27 (100%)
POWER POINT	22 (81%)	4 (16%)	0 (0%)	1 (3%)	0 (0%)	0 (0%)	27 (100%)
VIDEOS	5 (19%)	2 (7%)	6 (22%)	4 (16%)	1 (3%)	7 (26%)	27 (100%)
ON-LINE	8 (30%)	6 (22%)	3 (11%)	2 (7%)	1 (3%)	7 (26%)	27 (100%)
GROUP WORK	22 (81%)	5 (19%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	27 (100%)
CONFERENCING	1 (3%)	4 (16%)	5 (19%)	4 (16%)	1 (3%)	12 (45%)	27 (100%)
LECTURERS ONLY	0 (0%)	8 (30%)	1 (3%)	11 (41%)	6 (22%)	1 (3%)	27 (100%)

3.4 Opinion on Method of Assessment

Table 4 reveals that different methods of assessment variedly helped the students in their self development. If 100% of the respondents thought group presentations as an assessment method helped in their self development then 92% thought end of semester projects were helpful. Only 7% of the students strongly agreed that written classroom tests and examinations helped in their self development.

Table 4: opinion on method of assessment

The following assessment methods help(ed) me in self development

METHOD	STRONGLY AGREE	AGREE	UNDECIDED	DISAGREE	STRONGLY DISAGREE	BLANK	TOTAL
WRITTEN CLASSROOM TESTS AND EXAMINATIONS	2 (7%)	10 (37%)	5 (19%)	6 (22%)	4 (15%)	0 (0%)	27 (100%)
GROUP PRESENTATIONS	25 (93%)	2 (7%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	27 (100%)
END OF SEMESTER PROJECTS	21 (77%)	4 (15%)	1 (4%)	0 (0%)	0 (0%)	1 (4%)	27 (100%)

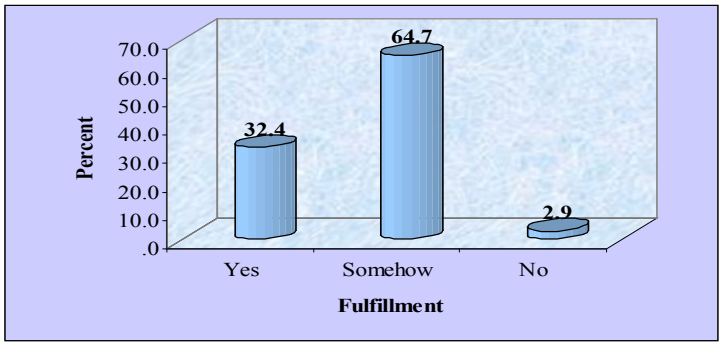
3.5 Expectations of Students on Joining the Course and Opinion on Degree of Fulfillment on Completion of the Course

The following were some of the course expectations of the finalist students on joining the entrepreneurship course:

( ) Acquire capacity to start, grow and sustain up a medium scale enterprise
(i) Complete the course and acquire the necessary skills
(ii) To attain in-depth understanding of the entrepreneurship field
(iii) Gain experience and entrepreneurship skills for self employment
(iv) Help to identify business start-up strategies and preparation of business plan
(v) To be a good investor and the best financial planner within an organization
(vi) To be able to initiate & sustain a business at a low cost and high profit
(vii) To be adequately equipped with knowledge and skills for successful business operations
(viii) To become a leading entrepreneur
(ix) To be competitive, creative and innovative in business start-ups
(x) To learn the do's and don'ts in relation to businessman to develop good ways to interact with people in the society
(xi) To learn and have adequate knowledge in management
(xii) To gain knowledge that will enable me to get a good job or run an own business
(xiii) To develop skills and competence in business identification starting and running profitably.

The listed expectations clearly show that students selecting to pursue entrepreneurship did so expecting that they would become entrepreneurs on completion of the course. When finalist students were asked if their expectations were met 65% thought their expectations were somehow met. 3% thought their expectations had not been met. Only 32% thought that their expectations had been met.

Figure 5: Expectations fulfillment



4.0 Discussion

Table 1 of the findings indicates that the lecture method of delivery dominates among entrepreneurship lecturers at Kenyan universities. In relation to the cone of learning by Dale Edgar (op. cit.), it can be concluded that Kenyan entrepreneurship university lecturers employ more of the passive approach to delivery than the active approach. The ability of passive methods of delivery to be used by the affective and psychomotor domains is minimal.

The traditional passive view of learning involves situations where material is delivered to students using a lecture-based format. In contrast, a more modern view of learning is constructivism, where students are expected to be active in the learning process by participating in discussion and/or collaborative activities (Fosnot, 1989).

Research on group-oriented discussion methods has shown that team learning and student-led discussions not only produce favorable student performance outcomes, but also foster greater participation, self confidence and leadership ability (Perkins & Saris, 2001; Yoder & Hochevar, 2005). Hunt, Haidet, Coverdale, and Richards (2003) examined student performance in team learning methods, finding positive learning outcomes as compared to traditional lecture-based methods. A comparison of lecture combined with discussion versus active, cooperative learning methods by Morgan, Whorton, & Gunsalus (2000) demonstrated that the use of the lecture combined with discussion resulted in superior retention of material among students.

The results of the cited studies favor constructivist, active learning methods and can be referred to as best practices. The teaching of entrepreneurship at Kenya universities – and hopefully African universities at large has, therefore, room for improvement.

Table 2 of the findings shows that written examinations are the most frequently used methods of assessment. The implications are that in relation to Bloom's taxonomy (op. cit); it is the cognitive domain of learning (which is known to be well-placed to prepare wage-employable graduates) that is mainly assessed. This may not be entirely surprising on the African continent. In many African countries there is some negative attitudes towards self-employment. Chigunta, F. (2006) in a paper presented at an expert group meeting on youth in Africa quotes African empirical studies that show that young people in Africa have a negative attitude towards self-employment, especially in the informal sector. This claim is collaborated by Okojie, (2003). These authors show that young Africans prefer formal employment to self-employment because of the 'white collar' mentality that they acquire from schools.

For entrepreneurship education in Africa skills and attitudes become very important. Without affective and psychomotor assessment it may be difficult to assess whether or not an entrepreneurship student has learned not just about but also for entrepreneurship. Best practices show that it is feasible within the entrepreneurship curricula to assess affective and psychomotor alongside cognitive achievements. This author has successfully practiced at JKUAT in his units.

Table 3 reveals the opinions of students about delivery methods. A majority of students thought that they gained better via active methods of delivery than via passive methods. That the lecture method received the highest disagreement about enabling the student to learn suggests that students agree with the Confucian philosophy of I hear and I forget, I see and I remember, I do and I understand.

Table 4 reveals that assessment methods that help the students feel that they have achieved the most are group presentations and semester projects. Written examinations are regarded the least in helping self-development. This implies that students want not just to think and comprehend but also feel and do. As Piaget noted, "at no level, at no state, even in the adult, can we find a behavior or a state which is purely cognitive without affect nor a purely affective state without a cognitive element involved" (as cited in Clark & Fiske, 1982, p. 130). McKeachie, (1976) emphasized the need to understand humans holistically; cognition and affect should not be separated. Entrepreneurship educators are expected to be familiar with the three domains of learning: cognitive, affective and psychomotor. The findings depicted in table 4 indicate that when Kenyan entrepreneurship lecturers teach and assess entrepreneurship education, they typically focus on instructional and assessment strategies in the cognitive domain of learning. This may be because of the perceived difficulty in measuring gains in the affective domain. This suggests that there may be need for retraining and refresher courses for such educators.

When students entered the entrepreneurship course they had end of course expectations. In general they expected to start their own businesses. Figure 5 shows that these expectations were not fully realized. One message is that not enough entrepreneurial culture was inculcated.

5.0 Conclusions

There are times when I joke that as a full professor and former chairman of a Kenyan quasi-government organization I have been in many rooms – small and big yet I have never been in a room bigger than "room for improvement". There is always room for improvement and this applies to the teaching of entrepreneurship in Kenya and indeed on the African continent. Although this study used Kenya as a case study there is evidence that many other African countries may be facing similar problems as Kenya in the teaching of entrepreneurship.

Reference was made to South Africa in the university of Pretoria PhD study cited elsewhere in this paper. In the year 2005 a study entitled "Entrepreneurship education at tertiary institutions in Rwanda: A situation analysis" was concluded. This study explored the provision of entrepreneurship education at higher education institutions (HEIS) in Rwanda with special reference to the levels of provision, support mechanisms, course objectives, contents, teaching and assessment methods to ascertain whether they are appropriately developed to prepare students for entrepreneurship as a career option. The findings showed that entrepreneurship education at HEIS in Rwanda is not appropriately developed to prepare students for entrepreneurship as a career option. The study went on to strongly suggest that HEIS in Rwanda should, among other things, integrate experiential learning in the curriculum.

On the 15th of March 2010 the Monitor of Uganda carried an article entitled "Entrepreneurship Education; Parody or Real Business? The article noted that a current difficult in Uganda's institutions of higher learning is how to prepare graduates to engage in productive work. It reported that in a bid to improve their possibilities in this area a new subject, entrepreneurship education was introduced in Uganda seven years ago. It went on to doubt if the subject is being taught properly to produce the desired graduates to engage in productive work. The article ended by proposing that entrepreneurship education in its present form requires the immediate attention of curriculum development authorities.

6.0 Recommendations

This paper provides a number of examples of good practice in entrepreneurship education. The discussion has both explicitly and implicitly pointed at some key areas for recommendations. Some recommendations are drawn directly from the findings of the paper while others have been deduced from the findings.

(i) Need to clarify the outcomes we seek from entrepreneurship education
(ii) Need to build effective entrepreneurship education in Kenya and on the continent
(iii) Need to develop effective entrepreneurship educators
(iv) Need to reshape the institutional paradigm
(v) Need to integrate entrepreneurs/professionals in curricula design and delivery
(vi) Need to securing public support/interventions

6.1 Clarifying the Outcomes we Seek from Higher Education

Greater clarity is needed regarding the purpose and goals of entrepreneurship education. As it stands today the purpose seems to be to produce intrapreneurs and not entrepreneurs. There is the danger that universities may be duplicating business studies and small business management courses. It should be remembered that entrepreneurship courses were introduced even when business and small business management courses already existed. There must have been a gap the new course was expected to fill. Entrepreneurship education is about developing attitudes,

behaviors and capacities at the individual level. It is also about the application of those skills and attitudes, which can take many forms during an individual's career, creating a range of long term benefits to society and the economy. Developing a clear framework for assessing entrepreneurship education is therefore necessary. Measuring the non-cognitive domains may be difficult; however, restricting assessment to the cognitive domain can result in falling far short of the known outcomes and impact of entrepreneurship education.

6.2 Building Effective Entrepreneurship Education

The methods of teaching and assessment of entrepreneurship education revealed by this research may be but a symptom of some underlying causes. In Nigeria there is a popular proverb (which may have its origins elsewhere) that *as you make your bed so you* must *lie on it.* Analogically as you design your curriculum so you must teach and assess it.

It is important for Africa to take the local cultural context into account when designing any entrepreneurship programme. In terms of delivery, a greater emphasis is needed on experiential and action learning. There are numerous pedagogies which can be utilized including local case studies, team projects, and activities with entrepreneurs. Using active learning methods is more complex than traditional teaching methods. It requires engaging students' feelings and emotions in the learning process. Educators/facilitators therefore must be able to create an open environment of trust in which students develop the necessary confidence to take risks. This directly leads to the next recommendation.

6.3 Developing Effective Educators

It is vital to create a critical mass of entrepreneurship educators able to create the right learning experiences for students. Growing the base of experienced educators not only means providing the necessary training and education but also requires expanding the definition of "educators" beyond professors to include entrepreneurs, alumni and even students. It may be necessary for the continent maybe through the African Union to set up a Centre or programme of excellence for producing entrepreneurship educators and trainers.

In order to use effective active learning approaches such as guest speakers, mobility and exchange of experience is needed between universities and the business world.

6.4 Reshaping the Institutional Paradigm

In Kenya and indeed elsewhere in Africa entrepreneurship education has come as an add-on aspect to the traditional academic disciplines. It is apparent that the traditional academics institutional culture, practice and policies often get in the way of developing an entrepreneurial spirit and environment within universities. We know for example that traditionally universities have been focused on ensuring students can secure future wage-employment. Today, universities must prepare students to work in a dynamic, rapidly changing entrepreneurial and global environment. This requires a complete paradigm shift for the entire university, including changing the fundamentals of how the university operates and its role in society. For entrepreneurship education to succeed institutions such as business incubators must become part and parcel of the university institutional framework.

6.5 Integrating Entrepreneurs/Professionals in Curricula Design and Delivery

Active and learning-by-doing methods integrate elements of practice into the learning process. This highlights the importance of actively engaging entrepreneurs and other professionals in both course design and delivery. These individuals also serve as role models, particularly if they are alumni of the university, as well as coaches and mentors. They also enhance entrepreneurial spirit within the university as well as create stronger links between the university and the local community.

6.6 Securing Public Support/Interventions

As indicated elsewhere in this paper in Kenya entrepreneurship training and education was an initiative of the government not the universities. The field of entrepreneurship education is still relatively young in the country and even younger on the continent. It is therefore important and necessary that governments continue with this support until entrepreneurship is embedded in a sustainable manner in universities across the continent.

The following specific recommendations for the continent's governments appear, to me, appealing:

(i) Provide support for Africa-wide (may be region-wide) mobility and exchanges of entrepreneurship educators

(ii) Improve the resource bases for institutions where entrepreneurship education is taking place e.g. set up business incubators, Publicize best practices models, initiate, encourage and support African local entrepreneurship case studies

(iii) Recognize and accept teaching by practitioners

(iv) Popularize entrepreneurship as a career path

(v) Create incentives for excelling entrepreneurship institutions.

References

Bird, B. J. (2002-2003. Learning Entrepreneurship Competences: the self-directed learning approach. *International Journal of Entrepreneurship Education*, **1**(2), pp. 203-227.

Black, L. (2003). The Contribution of 'World View' to Pupils' Attitudes on Enterprise, Entrepreneurship and Entrepreneurial Learning. Manchester Metropolitan University Business School working paper series. 03/05, Graduate Business School, Manchester Metropolitan University, Manchester.

Bloom, B., and Krathwohl, D. (1956). Taxonomy of educational objectives: The classification of educational goals, by a committee of college and university examiners. Handbook I: Cognitive Domain. New York: Longman, Green.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H. and Krathwohl, D. R. (1956). Taxonomy of Educational Objectives: Handbook 1 Cognitive Domain, Longmans, Green and Co Ltd, London.

Bowen et al, (2009). Management of business challenges among small and micro enterprises in Nairobi-Kenya. In KCA JOURNAL OF BUSINESS MANAGEMENT: VOL. 2, ISSUE 1 (2009).

Bwisa, H. M., (in print). Entrepreneurship theory and practice: a Kenyan perspective. The Jomo Kenyatta Foundation publishrs. Nairobi.

Chigunta, F., (2006). The Creation of Job/Work Opportunities and Income Generating Activities for Youth in Post-Conflict Countries. Paper presented at an Expert Group Meeting on Youth in Africa: Participation of Youth as Partners in Peace and Development in Post- Conflict Countries - 14 to 16 November 2006, Windhoek, Namibia.

Clark, M., Fiske, S. (Eds), (1982). Affect and Cognition: The 17th Annual Carnegie Symposium, Erlbaum, Hillsdale, NJ, pp.3-36.

Cooper, S., Bottomley, C. and Gordon, J. (2004). Stepping out of the Classroom and up the Ladder of Learning: an experimental learning approach to entrepreneurship education, Industry and Higher Learning, 18(1), pp. 11-22.

Dale, E. (1969). Audio Visual Methods in Teaching, (3rd ed). Holt, Rinehart, and Winston.
Dana, L.P. (1993) An International Survey of Entrepreneurship Education, *Journal of enterprising culture*, **1**(1), pp. 67-92.

ECA, (2000). Report of the Workshop on the theme, "Enhancing the Competitiveness of Africa - SMEs in Regional and Global trade: The Role of Support Services". Radisson Beach Hotel, Mauritius, 27 November to 1 December 2000.

Ehrste´n, M. and Kjellman, A. (2001). Rethinking Education: from homo industialis to homo entreprenaurus Preliminära forskarrapporter, Nr 218. Åbo: Åbo akademi.

European Commission Conference (2006). Entrepreneurship Education in Europe: Fostering Entrepreneurial Mindsets through Education and Learning. Workshop on Higher Education, October 26-27, 2006. Oslo, Norway.

FAO/WHO, (2005). Final Report on Regional Conference on Food Safety for Africa held between 3–6 October 2005, Harare, Zimbabwe. FAO, Rome.

Fayolle, A. (2001) Teaching Entrepreneurship: outcomes from an innovative experience, in H. Klandt (Ed.) IntEnt 98: internationalizing entrepreneurship education and training, pp 62-83. Köln: Joseph Eul Verlag.

Formica, P. (2002). Entrepreneurial Universities: the value of education in encouraging entrepreneurship. *Industri and Higher Education*, **16**(3), pp. 167-175.

Fosnot, C. T. *(*1989*).* Enquiring Teachers, Enquiring Learners: A Constructivist. Approach to Teaching. New York, New York: Teachers College Press.

Gorman, G. (1997) Some Research Perspectives on Entrepreneurship Education, Entreprise Education and Education for Small Business Management: a ten-year literature review, International Small Business Journal, 15(3), pp 56-77.

Henry, C. and Hill, H. (1999). European Entrepreneurship Education and Training – the need for evaluation. Small Firms: European strategies, growth & development, twenty two years of small business research: conference proceedings, vol. 1, pp. 615-634. Leeds: Institute for Small Business Affairs.

Henry, C., Hill, F. and Leitch, C. (2003). Entrepreneurship Education and Training. Aldershot: Ashgate.

Hofstede, G. (1980). Culture's consequences. Thousand Oaks, CA: Sage.

Hofstede, G., (2001). Culture's Consequences: Comparing Values, Behaviors, institutions, and Organizations across Nations. 2nd Ed., Thousand Oaks: Sage Publications.

Hunt, D., Haidet, P., Coverdale, J., & Richards, B. (2003). The effect of using team learning in an evidence-based medicine course for medical students. *Teaching and Learning in Medicine,* **15**(2), pp 131-139.

Kabogo, J. D. (2008). The status of entrepreneurship education in colleges and universities in sub-Saharan Africa. www.decisionscience.org/proceedings/DSI 2008/docs.

Kolb, D. A. (1984). Experiential learning: Experience as the source of learning and development. Englewood Cliffs, NJ: Prentice-Hall.

Kunene, T. R., (2008). A critical analysis of entrepreneurial and business skills in SMEs in the Textile and Clothing Industry in Johannesburg, Soth Africa. PhD Thesis, University of Pretoria.

Laukkanen, M. (2000). Exploring Alternative Approaches in High-level Entrepreneurship Education: creating micro-mechanisms for endgenous regional growth, Entrepreneurship and Regional Development, **12**(1), pp. 25-47.

McKeachie, W. (1976). Psychology in America's bicentennial year. *American Psychologist,* **31**, 819-833.

McKeachie, W. J. (1998). Teaching tips: Strategies, research and theory for for college and university teachers. Houghton-Mifflin.

Morgan, R., Whorton, J. and Gunsalus, C. (2000). A comparison of short term and long term retention: Lecture combined with discussion versus cooperative learning. Journal of Instructional Psychology, **27**(1), pp 53-58.

Mueller, J., Wyatt, R., Klandt , H. and Wee Liang, T. (2006). Can entrepreneurship be taught in an action-learning format? Journal of Asian entrepreneurship and sustainability. vol. ii, issue 2, 2006
Nelson, E. R., and Johnson, S. D. (1997). Entrepreneurship Education as a Strategic Approach to Economic Growth in Kenya (in Journal of Industrial Teacher Education. Vol. **35** (1) 1997).

OECD, (2004). 2nd OECD conference of ministers responsible for small and medium-sized enterprises (SMEs) on Promoting Entrepreneurship and Innovative SMEs in a Global Economy: Towards a more responsible and inclusive globalization. Istanbul, Turkey 3-5 June 2004.

Okojie, C. C. E. (2003). 'Employment creation for youth in Africa: the gender dimension'. Paper.

Prepared for the Expert Group Meeting on Jobs for Youth: National Strategies for Employment Promotion, Geneva, Switzerland, January, 15 – 16.

Perkins, D. and Saris, N. (2001). A jigsaw classroom technique for undergraduate statistics courses. *Teaching of Psychology,* **28**(2), pp 111-113.

Rae, D. and Carswell, M. (2001). Towards a Conceptual Understanding Of Entrepreneurial Learning, *Journal of small business and enterprise development*, **8**(2), pp. 150-158.

Rasmussen, E. A. and Sorheim, R. (2006). Action-based entrepreneurship education. Technovation, Volume 26, Issue2, February 2006, Pages 185-194.

Smith, Adam (1776). An Inquiry into the Nature and Causes of the Wealth of Nations. London: Methuen and Co., Ltd.

Suskie Linda (2009) Assessing Student Learning: A Common Sense Guide, 2nd Edition. Jossey-Bass.

Volker, Wild. (1997). Profit not for profit's sake: History and business culture of African entrepreneurs in Zimbabwe. Baobab books, Harare.

Yoder, J. and Hochevar, C. (2005). Encouraging active learning can improve students' performance on examinations. *Teaching of Psychology*, **32**(2), pp 91-95.

CAN SMALLHOLDERS CONTINUE TO EFFECTIVELY PARTICIPATE IN GLOBAL COMMODITY CHAINS? THE CASE OF FRENCH BEAN PRODUCTION IN KIRINYAGA REGION OF KENYA

F.N. Ondieki-Mwaura[1], L. M. Njoroge[2], J. J. Okello[3] and J. M. Bahemuka[4]
[1,2]Department of Social Sciences and Humanities, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[3]Department of Agricultural Economics,University of Nairobi, Kenya
[4]Department of Sociology,University of Nairobi, Kenya
Email: fnmwaura@ihrd.jkuat.ac.ke

Abstract
The participation of smallholders in global commodity chains such as export horticulture has often been characterised as problematic given the high transaction costs that these farmers face. The involvement of small holders in Kenya's export sector has therefore been hailed as an exception rather than the rule success story especially given the fact that it has developed largely under the private sector. However, changes in certain standards in export markets such food safety standards have posed a threat to these farmers' participation. For example, there is increasing evidence that exporters of fresh produce prefer to work with larger farmers or even engage in production rather than work with small farmers. If smallholders are going to continue participating in export horticulture value chains, they will have to among other things develop and participate in institutional arrangements that reduce the increasing transaction costs brought about by international food safety standards. This study aims to describe the various institutional arrangements that small farmers use to participate in export horticulture and the challenges and constraints they face within these arrangements. In addition, it will determine factors that affect farmers' choice of alternative institutional arrangements that exist. A survey of 240 farmers was carried out in Kirinyaga to obtain household data and 4 focus group discussions were held in each of the four districts in Kirinyaga. The case study methodology was used to gather in-depth information on the key institutional arrangements used by farmers. The study found that the most dominant institutional arrangements were selling individually to brokers, followed by selling as part of a group to an exporter. Some farmers were involved in more than one arrangement perhaps as a strategy to overcome the inherent disadvantages found in some arrangements.

Key words: Smallholders, participation, export horticulture, institutional arrangements

1.0 Introduction

Export horticultural sub-sector has continued to experience significant growth since the 1990s to become Kenya's leading export earner in 2007, ahead of tea and coffee. In 2008, export earnings from this sector grew to Sh. 73.7 billion up from Sh. 57.3 billion in 2007. Of the three main export horticultural products namely, fruits, vegetables and cut flowers, small farmers have played a more important role in the production of export vegetables. The largest vegetable exports by volume are French beans, which are also referred to as Green beans or Kenya beans, the latter giving an indication of Kenya's dominance in the export markets which are mainly the United Kingdom, France and Germany (Okado, 2000). In 2003, Kenya was the world's largest exporter of French Beans. French bean production and export by small scale farmers was the focus of this study. Although export horticulture continues to grow becoming Kenya's leading foreign exchange earner, there are concerns that the benefits from this lucrative sector may bypass small scale producers who initially formed the bulk of producers in this sector. A key challenge for many small holders has been the changes that have occurred in the main export markets that have necessitated the enforcement of stringent food safety and quality measures which in turn threaten the procurement of produce from small farmers in developing countries (Dolan *et al.,* 2001; Henson *et al.,* 2008; Vermeulan *et al.,* 2008).

These requirements have been shown to threaten the participation of small producers in developing countries largely due to their financial investment needed to meet these requirements (Dolan, 2001; Graffham *et al*., 2007 and Jaffee, 2008). The major destination for Kenya's French beans is the European Union with the United Kingdom (UK) accounting for 53%, French markets 24% and the Netherlands 7% of the market. Collectively the European market introduced a food quality and safety standard referred to as the EUREPGAP protocol for fresh fruits and vegetables in September 2003 which became mandatory in January 2004. It consists of control points that cover aspects of agricultural production from seed to delivery of product at farm-gate. It also includes environmental and social aspects. Kenyan French bean exporters therefore have to seek certification under this protocol in order to continue sending their produce to these markets. It is believed that due to the high costs involved in both getting many small farmers certified as well monitoring their compliance to the standards, exporters will prefer to work with larger farmers who can meet certification costs easily or they may prefer to move into direct production. This in turn threatens to lock out smallholders from export horticulture (McCulloch and5 Ota, 2002; Dolan, 2001).

An important aspect of export horticulture development in Kenya has been the fact that it has developed largely within private sector hands. The government has by and large played a regulatory role through the Horticultural Crops Development Authority (HCDA). With the absence of direct government involvement and subsequently state run marketing boards, the export of horticultural products has resulted in the evolution of various marketing institutional arrangements. An institutional arrangement, also known as governance structure, is a term used within the New Institutional Economics (NIE) to describe a structure within which members of a society individually or collectively cooperate. Doward *et al*., 1998, define institutional arrangements as arrangements between economic units that govern the way in which these units can cooperate and/or compete. These economic units, e.g., farmers and exporters must find arrangements that help to reduce transaction costs that they face. Transaction costs are defined as the costs incurred in the process of exchanging good and services and include the costs of identifying and screening different trading opportunities, outlets and partners, the cost of negotiating trading agreements, the cost of transferring the goods, services and ownership rights as well as the costs of monitoring the trade conditions to ensure that they are being complied with and enforcing the consequences of breaching the terms of agreement (Jaffee, 1995). Buyers and sellers will seek to form and participate in institutional arrangements that minimise these transaction costs.

This study attempted to identify the various marketing institutional arrangements that are used by small farmers involved in export French bean value chain and determine which ones better enabled their participation in the sector in order to ensure that the farmers continued to derive sustainable livelihoods from this sub-sector. This study therefore aimed to address a key challenges faced by small farmers in Kenya's horticultural sector by addressing the following questions; what institutional arrangements were available for them to participate in and what constraints did they face as they participated in these arrangements?

2.0 Methodology

2.1 Study Area

This study focused on farmers within Kirinyaga area, which has had a long history of growing this crop (Kyengo Per.Comm 2008). Kirinyaga region (which was formerly Kirinyaga District has now been split into 4 districts- Kirinyaga East, Kirinyaga kWest, Kirinyaga Central and Kirinyaga South Districts) and is situated on the southern slopes of Mt. Kenya. It covers an area of approximately 1478 sq. km with a population density of 309 persons per km^2, and an estimated population of 500,000 people (census 1999). It borders Nyeri and Murang`a to the West, Embu to the East and Mbeere to the south and is approximately 100 km, North-East from Nairobi.

2.2 Research Design

This study primarily used the survey type of research which is defined by Mugenda & Mugenda (1999) as an attempt to collect data and from members of a population in order to determine the current status of that population with respect to one or more variables. One of the main advantages of this approach is that it enables the researcher to collect original data for the purposes of describing a population which is too large to observe directly (ibid.). The survey approach was complemented by qualitative approaches namely case study, focus group discussions and key informant interviews. A case study according to Yin (2009) is an empirical inquiry that investigates a contemporary phenomenon in-depth and within its real-life context especially when the boundaries between phenomenon and context are not clearly evident. The case method was also employed in identifying and describing the nature of institutional arrangements.

2.3 Sample Size and Sampling Procedure

The field survey was carried out in August and September 2010.The sample size for this study was 240 farm households involved in French bean production in 2009. The sampling procedure used for this study was stratified random sampling, in order to achieve a high degree of representation. The sub-location with the highest concentrations of French bean farms within each of the four districts was selected. The exception to this is Kirinyaga South where three sub-locations were used accounting for almost 50% of the sample because this district alone accounts for about 50% of the total French bean production in Kirinyaga. Farmers lists were generated from these areas and households randomly sampled for the questionnaire survey. The table below summarises the sampling results.

Table 1: Sampling results

District	*Location*	*Sub-location*	*No. of French bean farmers*
Kirinyaga Central	Kanyakine	Kathare	40

Kirinyaga West	Mwerua	Gitaku	40
Kirinyaga East	Kirima	Mutige	40
Kirinyaga South	Tebere Murinduko Kangai	Kiarukungu Kamunyange Gathiga	40 40 40*
TOTAL			**240**

Source: Author

Data for this sub-location is still being cleaned and analysed

2.4 Data Collection Tools

The following data collection tools were used:

(i) A questionnaire that was administered to sampled households
(ii) Key informant interviews with the District Horticultural officer, FPEAK official, farmer group officials
(iii) Focus group discussion in every district

2.5 Data Analysis

Data entry and analysis was done using Statistical Package for Social Sciences (SPSS). Descriptive statistics were used to analyse characteristics of the sample. Key informant interviews provided data used to identify and describe the institutional arrangements as well as give in-depth information on the nature and operation of these arrangements. The results presented below are preliminary results from the study.

3.0 Results and Discussion

3.1 Description of Sample

There were 220 respondents who gave information on household composition, farm characteristics, household income and enterprises as well as French bean production on their farms. In terms of infrastructure, the mean distance to the nearest market is 3.2 km for French bean farmers, while that to the nearest agricultural office is 8.2km. The mean distance to the nearest electricity hook-up was 1.1 km. In terms of the type of road leading to the nearest market, 48% of respondents used a non-paved road, 37% used murram while only 14% had tarmac on the road leading to the nearest market.

The mean size of land was 2.1 acres for and in terms of ownership rights on the land they were farming, 30% were on land with a title,48% on land that had been sub-divided but had no title, 18% was leased while 3.2% were on land given as gifts by relatives. 75% of the respondents reported that the soil type on their farm was loam, 0.5% clay and 24.5% clayloam. 65.4% reported that the land they farmed on was relatively sloppy, while 27.4% farmed on flat land. Only 7.4% of the respondents claimed that the land was very slopy. 95% of the respondents had irrigation on their land with 65% of these using furrow irrigation.

In terms of household characteristics the mean age of the farmers was 41.6, while the mean number of years spent in school was 9.4 years. The mean asset value for these farmers was Kshs. 130,885.70 (excluding the value of land).

3.1.1 Description of institutional arrangements

Eight institutional arrangements were identified as being used by farmers to market their French beans during the focus group discussions held in March-April 2010. They are:

(i) Selling individually to exporter

(ii) Selling as part of a group to an exporter

The two channels involve selling directly to a buyer who is an exporter of French bean. The key difference between the two is that the buyer will work with an individual farmer in the former while in the second he/she will work with a group of farmers. In order for one to get an individual contract one has to plant at 3 acres of French beans at any planting which therefore excludes many small farmers. The second arrangement is more commonly used where a group of farmers will approach an exporter to buy produce with them. A written contract is often negotiated between the group officials and the exporter and will include among other things the grade to produce, the price per kilo, the quantity the exporter will purchase at certain intervals for example weekly or twice weekly, pest contol methods to use as well as technical advice. Farmers may also be provided with seeds and pesticides on credit and transport of the produce from the grading shade to the packhouse in Nairobi. This cost is deducted from the farmers' earnings. Rules against side-selling are also specified as well as the requirements necessary for a farmer to meet certain global standards including a grading shed, toilet facilities and protective gear. Penalties for not adhering to all the set out rules and regulations are also spelt out. The group operates independently of the exporter (unlike outgrower schemes where farmers are organised by an exporter) and will often have a constitution which regulates its activities and will be registered by the relevant government departments. Many of them also operate like saccos where farmers buy shares (usually deducted from French bean earnings) and against which farmers can borrow.

(iii) Selling individually to exporter agent

(iv) Selling as part of a group to an exporter agent

The buyer in these two institutional arrangements is contracted by an export company to identify and contract either individuals or groups of farmers to produce. He is based within the locality of the farmers and therefore is familiar with the area and with the farmers, unlike the exporter who is based in Nairobi and only makes periodic visits to the area. Apart from this difference, the mode of operation is similar to the arrangements involving the exporter.

(v) Selling individually to a broker/other farmer within the area

(vi) Selling as part of a group to broker/other farmer within the area

In these arrangements the buyer is commonly referred to as a broker and is often a local farmer. He is very familiar with the farmers in the area and he is able to easily identify which farmers have a crop of French beans. In this channel, the farmers are rarely provided with any information or assistance. These brokers operate seasonally, especially when there is scarcity of French beans and they are able to acquire produce from farmers by buying at very high prices. They are often accused of raiding farmers operating under the exporter arrangements and buying produce from them that should have gone to the exporter. However, it is important to note that there are farmers 9 either individuals or groups) who produce just to sell through this channel.

(vii) Selling individually to a broker from outside the area

(viii) Selling as part of a group to a broker from outside the area

In these arrangements the broker or middleman is from outside of the area and will often go form farm to farm or park his truck in a strategic place where farmers can go and sell their produce to him. He does not have as much knowledge of the area and will often use local scouts to determine where he can get produce. The mode of operation is very similar to that of the local broker.

3.1.2 Operations of the Institutional Arrangements

The extent to which each of the arrangements is used by farmers was determined by district and sub-location as indicated in the tables below.

Table 2: Summary of use institutional arrangements per district

	District				
Institutional arrangements	Kirinyaga East	Kirinyaga West	Kirinyaga Central	Kirinyaga South	Total
Selling individually to exporter	4 (6.5)	3 (7.9)	8 (17.0)	27 (22.0)	42
Selling as part of a group to exporter	22 (36.0)	24 (63.2)	14 (29.8)	5 (4.0)	65
Selling individually to exporter agent	2 (3.3)	1 (2.6)	6 (12.8)	8 (6.5)	17
Selling as part of group to exporter agent	8 (13.1)	10 (26.3)	1 (2.1)	1 (0.8)	20
Selling individually to broker/other farmer within area	17 (27.9)	0 (0)	15 (31.9)	44 (35.5)	76
Selling as part of a group to broker/other farmer within area	3 (5.0)	0 (0)	1 (2.1)	7 (5.7)	11
Selling individually to broker/other farmer from outside the area	5 (8.2)	0 (0)	2 (4.3)	25 (20.3)	32
Selling as part of a group to broker/other farmer from outside the area	0 (0)	0 (0)	0 (0)	6 (4.9)	6
TOTAL	61	38	47	123	269

Source: Author, Field Survey, 2010

Notes:

(i) ( ) percentage

(ii) Percentages and totals based on responses

Table 3: Summary of use institutional arrangements per location

	Location					
Institutional arrangements	Mwerua	Kanyakine	Tebere	Kirima	Murinduko	Total
Selling individually to exporter	3 (7.9)	8 (17.0)	5 (6.5)	4 (6.6)	22 (47.8)	42
Selling as part of a group to exporter	24 (63.2)	14 (29.8)	5 (6.5)	22 (36.1)	0 (0)	65
Selling individually to exporter	1	6	3	2	5	17

agent	(2.6)	(12.8)	(3.9)	(3.3)	(10.9)	
Selling as part of group to exporter agent	10 (26.3)	1 (2.1)	1 (1.3)	8 (13.1)	0 (0)	20
Selling individually to broker/other farmer within area	0 (0)	15 (31.9)	30 (39.0)	17 (27.9)	14 (30.4)	76
Selling as part of a group to broker/other farmer within area	0 (0)	1 (2.1)	7 (9.1)	3 (4.9)	0 (0)	11
Selling individually to broker/other farmer from outside the area	0 (0)	2 (4.3)	20 (26.0)	5 (8.2)	5 (10.9)	32
Selling as part of a group to broker/other farmer from outside the area	0 (0)	0 (0)	6 (7.8)	0 (0)	0 (0)	6
Total	38	47	77	61	46	269

Source: Author, Field Survey, 2010

Notes:
(i) ( ) percentage
(ii) Percentages and totals based on responses
(iii) Data for Kangai location missing

From the two tables it can be concluded that the most dominant institutional arrangement used by farmers in Kirinyaga is selling individually to a broker or other farmer within the area. It is then followed by selling as part of a group to an exporter. The only exception to this trend is Kirinyaga West where selling as part of a group to an exporter is the most dominant arrangement followed by selling individually to a broker from within the area. This is perhaps because the type of French bean grown predominantly in Kirinyaga West is the canning variety which is only bought by one buyer. Out of the 269 responses above, it was noted that 188 responses were those of farmers using only one arrangement to market their French beans. Other farmers indicated that they used more than one arrangement, specifically, 58 respondents used 2 arrangements, 21 used 3 arrangements and 2 used 4 arrangements. Interestingly, for those who participated in more than one arrangement, the most preferred arrangement was the selling as part of a group to an exporter.

The length of participation in the preferred arrangement was between 1-25 years with most farmers having participated for between 3 to 10 years. In terms of the type of agreement that exist between buyer and farmer, the most common type of agreement for those who participated in selling individually to exporter was an individual written contract(37.5%), while for those who participated in the selling as part of a group, it was a group written contract (92.5%). Those who participated in the broker arrangement were split between individual verbal agreement (38%) and no agreement (38%).

In terms of assistance that growers get from buyers, it is evident that those who participate in channels where the buyer is an exporter or exporter agent receive more information than those whose buyers are brokers as shown in the table below.

Table 4: Information of assistance received within the various arrangements

	Received Information/ Assistance on					
Institutional arrangements	Quantity to produce	Grade to produce	Seeds	Inputs	Spraying schedule	
Selling individually to exporter	40%	84%	65%	28%	87.5%	
Selling as part of a group to exporter	78%	90%	82%	24%	73%	
Selling individually to exporter agent	42%	42%	42%	28%	57%	
Selling as part of group to exporter agent	56%	81%	12%	6%	25%	
Selling individually to broker/other farmer within area	0%	37%	0%	0%	3%	
Selling as part of a group to broker/other farmer within area	0%	0%	0%	0%	0%	
Selling individually to broker/other farmer from outside the area	0%	0%	0%	0%	0%	
Selling as part of a group to broker/other farmer from outside the area	0%	0%	0%	0%	0%	
Total						

Source: Author, Field survey, 2010

3.2 Advantages and Disadvantages of the Various Institutional Arrangements

Each of the arrangements identified above has advantages and disadvantages associated with them. Within the selling to individual exporter the most important advantage identified was access to a guaranteed market (50%). In the selling to exporter as part of a group, access to guaranteed market (75%) and access to technical assistance (25%) were identified as most important benefits of the arrangements. For all the broker arrangements, the most important advantage cited was the higher price compared to other arrangements.

In terms of disadvantages, in the selling individually to exporter, the most important disadvantage the high reject rates (66%) and the buyer not keeping to terms of the agreement. In the selling as part of a group to exporter, equal weight was given to lower price, high reject rates and buyer not keeping to the terms of the agreement all at 33%.
In the broker channel, uncertain market accounted for 50% of all responses and the lack of credit and lack of assistance from buyer both accounted for 33% of all responses.

4.0 Conclusion

The broker channel specifically, the selling individually is the most dominant arrangement in the four out of five locations where the sampled households were located. And while the main advantage of this arrangement is that it could offer higher prices than most

arrangements, its ability to help farmers participate sustainably over a long period of time in export French bean trade is suspect for two major reasons. One, it is not a secure marketing arrangement as no long-term relationships are established between buyer and seller and the arrangement is usually active when there is a scarcity of produce. Secondly, and perhaps more importantly, this arrangement does not provide farmers with assistance necessary to stay competitive in global markets. Specifically, this arrangement does not provide a means for farmers to obtain certification to the necessary food and safety standards that have proliferated export markets. As a result the future of participants of this arrangement is insecure.

The second most dominant arrangement is the selling as a group to an exporter. It is the most dominant arrangement in Kirinyaga West where the canning variety of French bean is grown. This arrangement was also the most preferred arrangement where farmers participated in more than one. Given the advantages associated with this arrangement including access to technical assistance, international certification and the possibility of a guaranteed market perhaps more needs to be done to make it more attractive to farmers. Specifically, more needs to be done to ensure that exporters are held accountable to terms of agreement such as buying produce in the quantities and frequencies agreed on. In addition, there is need for transparency in determining the grading and the subsequent rejection of produce. Furthermore, many of these exporters tend to offer a fixed price for the produce which many farmers feel is too low. It is one of the reasons why farmers side-sell to brokers. This is one area that requires urgent attention. Finally there is need to educate farmers on the need to use their collective bargaining power to negotiate contracts effectively and ensure that all members of their groups keep to the contract terms.

References

Dolan, C., Humphrey, J. and Harris-Pascal, C. (2001). Horticulture commodity chains: the impact of the UK market on the African fresh vegetable industry, IDS Working paper 96.

Doward, .A., Kydd, J. and Poulton, C. (**eds**) (1998). Smallholder Cash crop production under market liberalization: A new institutional economics perspective. CAB International.

Graffham, A., Karehu, E. and MacGregor, J. (2007). Impact of EurepGAP on Small-Scale Vegetable Growers in Kenya. Fresah Perspectives Agrifood Standards and Pro-por Growth in Africa, Issue 2. IIED, DFID and NRI.

Henson, S., Jaffee, S., Cranfield, J., Blandon, J. and Siegel, P. (2008). Linking African Smallholders to High-Value Markets: Practitioner Perspectives on Benefits, Constraints and Interventions. Policy Research Working Paper 4573. Agriculture and Rural Development Department, The World Bank.

Jaffee, S. (1995). The many faces of success: The development of Kenyan Horticultural Exports in Marketing Africa's High-value Foods: Comparative experiences of an emergent private sector. The World Bank.

McCulloch, N. and Ota Masako (2002). Export Horticulture and Poverty in Kenya: University of Sussex, Brighton, England IDS Working Paper 174 Globalisation and Poverty series.

Okado, M. (2000). Background Paper on Kenya Off-Season and Speciality Fresh Vegetables and Fruits: Lessons of experience form the Kenyan Horticultural Industry. United Nations Conference in Trade and Development.

Vermeulen, S., Woodhill, J., Proctor, F. and Delnoye, R. (2008). Chain-Wide Learning for Inclusive Agrifood Market Development: A Guide to Multi-Stakeholder Processes for Linking Small-Scale Producers to Modern Markets. Netherlands: IIED, UK & CD& IC, Wageningen University and Research Centre.

RE-VISIONING KENYA'S SOCIAL DEVELOPMENT AGENDA FOR INDUSTRIALIZATION AND SUSTAINABLE DEVELOPMENT

J. A. Misati and D. M. Mngoda
Jomo Kenyatta university of Agriculture and Technology, Nairobi, Kenya

Abstract
Kenya aspires to become a globally competitive and prosperous Nation with high quality of life by the year 2030. This quest began soon after independence with the realization the government needed to put in place measures to ensure rapid economic development and social progress for all citizens. A premier social policy; sessional paper no. 1 of 1965 on African Socialism and its application to planning in Kenya envisaged to spur economic growth by rapid industrialization and development of the productive agricultural sector in rural areas failed to embrace decentralized decision-making and local participation and by 1970's the inadequacies of the economic growth & top down approaches had become apparent. In the subsequent decades, the government formulated and implemented various policies and reform measures aimed at decentralization efforts to enhance equity and faster pro-poor growth. In the education sector, the Gachathi report (1976) and Mackay report (1981) among others sought to emphasize the need for education for practical orientation and self reliance , While in the health sector the government launched its proposal for far reaching changes placing greater emphasis upon decentralized priority setting and equitable allocation of resources alongside the national development plans. In 1983, the District Focus for Rural Development (DFRD) strategy was launched with the sole aim of making the district the locus for project identification and implementation. More recently, the Economic Recovery Strategy for Wealth and Employment Creation (ERSEWC 2003) which outlined interventions and strategies for reducing poverty aimed at enhancing access to the benefits of economic growth by the most disadvantaged members of the society was formulated, culminating in the current blue –print, The Kenya Vision 2030. This paper assesses the reforms and their resultant impacts on social development in Kenya over the decades, with greater emphasis placed on the current programmes. It argues that whereas the strategy's foundation is erected on the economic, social and political pillars, strengthening the on-going institutional and governance reforms will go a long way in raising efficiency in the production and social sectors. Data was obtained mainly from secondary sources including; sessional papers, National development plans and statistical abstracts. Discourse analysis involving a critical review of the existing literature indicates that the implementation of various development policies notwithstanding, poverty and other development related setbacks persisted. It is recommended that constructive civic engagement, cubing brain drain among highly trained technocrats, ensuring sustainable peace and tranquility especially in the neighboring countries and restoring financial discipline including curbing corruption will go a long way in guarding against depleting the much prized gusto necessary for propelling the county towards industrialization by the year 2030.

Key words: Participatory governance, vision 2030, social development, decentralisation

1.0 Introduction

At independence Kenya pursued a development strategy that was informed by African Socialism (Republic of Kenya, 1964). The policy placed emphasis on rapid economic growth rather than human development and assumed that poverty, unemployment and income disparities would improve as a result of a robust economy. Access to education, health services and political participation were envisioned from a purely economic perspective. With the implementation of the Structural Adjustment Programmes (SAP'S) drastic measures involving trade liberalization and reduction in government expenditure led to imposition of user fees on such social amenities as education and health and diminished the access to these services by the poor and vulnerable. At the same time, the country's economy grew by an average of 6% between 1964 and 1980 and by 4% between 1980 and 1990, but between 1990 to 2002 the country experienced an annual GDP growth of 1.9% while the population grew at 2.9% annually. However, even with sustained economic recovery and declines in absolute poverty from 53% to 46% by 2007, Kenya remains one of the poorest countries in Africa.

In order to overcome the persistent development challenges and bottlenecks, the country developed a long term National Development strategy called "Kenya Vision 2030" which envisions a globally competitive and prosperous nation with a high quality of life by 2030. The Vision is anchored on three key pillars; The Economic and the Social Pillars aimed at achieving a just and cohesive society enjoying equitable social development in a clean and secure environment and Political pillar aimed at establishing an accountable democratic political system. Despite the ambitious formulations in the document, which is on its third year of implementation, recent research findings indicate that the government social policy has not reduced poverty nor inequality, with all indications to the contrary – economic growth has increased and widened inequality and deepened poverty (Bujra and Keriga, 2009).

1.1 Objectives

The objectives of the paper are to assess the successive social reform Agenda and its effectiveness in enhancing sustainable development in Kenya; examine the nexus among the various pillars that constitute Vision 2030 and recommend viable strategies to be adopted in order to propel the country towards the status of a newly industrialized Nation by the year 2030.

1.2 Overview of Social Policy Development in Kenya since Independence

In all countries education systems differ in their organization, structure, content and have different goals. These goals tend to fall under four major categories; Utilitarianism, Social, Cultural and Personal goals. Of interest to this paper is the aspect of utilitarianism. The goals of utilitarianism are considered at two levels; First It is the duty of the state to invest in education of her people to produce manpower for national development. Secondly, From the individual point of view the benefits of education should be; the ability to read and write, to eradicate poverty and illiteracy. Social goals of education emphasize the importance of socialization i.e how to fit into school life, at home, in the community and society at large. In every society culture is important .Its values and virtues should be taught to the youth through the promotion of social sciences. Finally every education system should foster personal goals. The individual should be able to develop their potentialities to attain self- actualization. The goals can be achieved as long as they are supported by the community to the extent to which a country can stretch her limited resources, both human and physical capital. Education, therefore, has turned out to be one of the most important social institutions in modern society that can be relied upon to foster sustainable development. It is important to note that education transmits skills, knowledge, norms and values from generation to generation.

According to Eshiwani (1984) education aims at socializing individuals to fit into their society so as to function adequately within it when they become adults. Nyerere (1967) says that the purpose of

education is to transmit from one generation to the next the accumulated wisdom and knowledge of the society and prepare the young people for their future membership of the society and their active participation in its maintenance or development.

The Ominde Commission report (1965) was a master piece in that it was the only one that catered for utilitarian, social, cultural and personal goals of education. The commission emphasized the development of manpower for nation building. The emphasis was to make education provide manpower for national development. This was reiterated by Ndegwa commission (1971) whose goals and objectives were echoed in the First and Second Development Plans of 1964-70 and 1970 - 1974 respectively. The government was committed to expanding educational opportunities to meet public demand for education.

The third development plan (1979-1988) stressed on tackling the constraints imposed on development by under utilization of human resources and the lack of appropriate skills at all levels. The education system was called upon to provide the high level skills needed for; economic and industrial growth, the vocational, technical, training for employment and promotion of attitudes favorable for development.

The Gachathi report (NCEOP, 1976) emphasized restructuring the education system to meet the demands of the country. The commission related education to employment opportunities and was critical to the educational system then. The Mackay commission (1981) reported that education is aimed at enabling the youth to apply a more effective role in the life of the ration by imparting to them necessary skills and knowledge and inculcating the right attitudes .The commission established a second university which aimed at emphasizing on vocation – based courses, stressed the importance of education in serving the needs of national development. The Mackay report recommended the initiation of the 8-4-4 system of education, geared towards practical and technical education. The new education system was designed to provide life-long education to make individuals self-sufficient and in and productive in agriculture, industry and any other services.

According to the National Development plan (2002-2008) emphasis was laid on education training and capacity and asserted, education is a functional strategy for human resource development and subsequent economic development. The vocational and technical training for artisan, craftsmen technician, technologists and masters of technology will go a long way to promote industrial development.

In the vision 2030 the Government of Kenya is committed to the provision of quality education, training and research for all Kenyans .The major reforms the education sector has undergone include ;The launch and implementation of free primary education (FPE) in January 2003,Development of sessional paper No.1 of 2005 on Policy Frame work for Education, Training and Research , Adoption of sector wide Approach (SWAO) to planning and financing of education and training ,Development and implementation of Kenya Education Sector Support Programme (KESSP) which is an investment programme that allows stakeholders to support the sector in the medium term , and Recently introduced Free Day Secondary Education (FDSE) .

In the Health sector, an explicit policy focusing on curative and preventive services was published in Sessional Paper No. 1 of 1965 on Africa socialism and its application to planning in Kenya and by 1965 provision of health care was declared free (Kimelu *et al*, 2004) . In 1970, the Kenyan Government took over the running of services previously run by local councils resulting in an increase in number of rural health facilities provided by government. However, with decline of world economic performance between late 1970's to 1980's a policy shift commonly referred to as the Structural Adjustment Programmes (SAPS) leading to the formation of the *Kenya Health Policy*

Framework of 1994 and *National Health sector strategic plan* 1999-2004. A key feature of the latter was the introduction of cost –sharing, which was, however not sustainable due to increasing poverty level and declining performance which was recorded at its worst in the period 2000-2002. In order to reduce inequalities in health care, the *National health sector strategic plan* (NHSSP-11:2005-2010) currently on implementation was formulated.

2.0 An assessment of Kenya's Social Development Policy since Independence

From the foregoing discussion, it is evident that various attempts have been made at initiating viable development strategies geared towards propelling the country towards prosperity anchored on an all –round adoption of science, technology and innovation as an implementation tool. In education, attempts have been made by the Government to attain an Educational system capable of catering for the needs of the society, creation of manpower for nation buildings provision of appropriate skills at all levels needed for economic and Industrial growth.

Despite all the mayor strides made in education and training a number of challenges still persist. These include the cost of training, inequality in access, high wastage rates, problem of relevance and quality and under enrolment in key post - school courses for developing a labour force for industrialization (Republic Of Kenya, 2002) .With regard to quality and relevance, concern continues to be raised on failure to satisfactorily inculcate a modern scientific culture and imbue the learners with desirable social skills and values. This is attributed to inadequacies in the provision and maintenance of essential physical facilities, instructional and research materials and human resource capacity. Variously, there has been the problem of tending to emphasize on certification at the expense of vocationalization and skills acquisition.

In vision 2030 the social pillar, which houses the education sector, Kenya has designed an impressive goal for quality education, training and research to her citizens for development and enhanced well being. This was a replica of the previous successive impressive commissions of inquiry tasked with reforming the country's education system. The programmes designed were never fully implemented but ended up emphasizing examination oriented practices and other malpractices.

Secondly, a country has to invest in, among other areas, health if it has to accumulate the human capital necessary for sustainable economic growth. Provision Of health care is not only a basic need but a preliquisite for developments (BUJRA et al, 2009). Healthy individuals increase their value in the labour markets. An increase in productivity frees up resources to create new technologies and wealth, eventually resulting in increased economic growth and human welfare (KIPPRA, 2009) .The health sector is the key components addressing equity under the social pillar in vision 2030 (Republic of Kenya, 2008) .The Key challenges in the health sector are; Low level of life expectance, inadequate funding, health infrastructure and personnel. In order to raise the level of life expectancy, the country needs to reforms its healthy goals to reduce Infant Mortality. Thus, more funds should be allocated to the fight against the burden of the disease including prevention of HIV AIDS by increasing the coverage for ART, ARVS, and PMTC, VCT treatment of opportunistic infections such as T.B and Malaria among others. Even with continued health care policy revision, health care is elusive to most households and individuals especially in rural areas.

3.0 Conclusions and Recommendations

3.1 Conclusions

The education sector remains the single most important vehicle for propelling the country towards sustainable economic development and industrialization. For this reason , Several successive Education policies and plans have been designed since independence .In the same vein, Health care provision has not improved much even with the continuous policy revision. A quick glimpse of the indicators as reflected by the Child Mortality Rates, Maternal Mortality and Life expectancy indicate

that not much has changed in the ability of the health care system to improve well being of individuals. Quality of health care system is still low; access is limited; disease burden continues to affect the populace and health care disparities still characterized the health landscape in Kenya .Most important, it should be observed that the realization of the vision is not cast on stone and, therefore, has several assumptions that must hold for it to be a reality. They include; Macro-Economic stability, sustained governance reforms, adequate energy for wealth creation and enhanced security to make the environment conducive for constructive civic engagement and quality entrepreneurship (Misati and Mwenzwa, 2010).

3.2 Recommendations

This study has illuminated the critical role played by the key social welfare services provision in the long term realization of the country's vision of becoming a newly industrialized country in a span of 20 –30 years as well as the implications of lack of a transformed and reformed national governance structures characterized by high level executive capability consistent with a rapidly industrializing country. In order to enhance decentralization and public participation in governance, the devolved funds should be used to strengthen decentralization of development projects at the community level. To attain this goal; improved planning, prioritization and coordination of such projects at the local level should be accorded priority.

As already pointed out, the three pillars of the vision are seen to affect one another in a triangular relationship, such that adverse performance of one pillar negatively affects the others. For instance political maladministration (political pillar) negatively affects economic growth (Economic Pillar) as investors withdraw, eventually reversing the anticipated gains in development. Hence challenges in one sector presents difficulties for effective implementation of the entire blue – print. Furthermore, there are several bottlenecks that stand on the way, hence making the progress towards 2030 a mirage.

To start with, unconstructive civic engagement manifested in the form of ethnicity and ethnic conflicts have had a negative impact on peaceful co-existence and nation building. It is to be noted that these occurrences have been seen to escalate with the advent of multiparty politics in Kenya in the 1990s with disastrous impact on welfare indicators. For example, while the implementation of the ERSWEC has had numerous gains in the development of the country, the 2007/2008 post election violence reversed many of the gains made through destruction of property, loss of lives and disruption of economic opportunities, all of which have a direct relationship to national development. It is important that we quantify the impact of the violence and sensitize the citizenry, particularly the youth who are more prone to manipulation and misuse as weapons of violence.

Ill-health in Kenya including HIV/AIDS, malaria among other diseases has over a long time strained the health care system and taken a high toll on personnel. This has, therefore, adversely affected the implementation of development projects and nation building. In addition, the health sector has over a long time been dependent on development partners and their withdrawal has had a devastating impact on access to health services. This is more pronounced among the citizens in the lower socio-economic echelons who mainly depend on public health facilities. Moreover, there has been a considerable brain drain among highly trained technocrats, which in turn affects the quality of health care services. Most important, Kenya is known to rely heavily on Foreign Direct Investment (FDI) and Overseas Development Assistance (ODA), which are not only unguaranteed, but also unsustainable. Consequently, it is going to be a tall order for the country to achieve most of the vision 2030 targets in the absence of seriously addressing the foregoing issues.

It is widely acknowledged that education plays a central role in the development of any country and therefore the welfare of its citizenry. In Kenya, gender, regional and socio-economic disparities

regarding access to education are so acute. It is skewed in favour of males, some regions and the upper and middle income echelons (Republic of Kenya, 2008). The foregoing has far reaching implications on gender and regional equity, balanced national development and in effect the achievement of Kenya Vision 2030 targets. For example, the arid, semi-arid, urban informal settlements and other marginalized areas do not only lack viable infrastructure, but also the necessary personnel, which hampers delivery of quality education services. Suffice it to mention, bridging the disparities would require pumping enormous resources in this sector. In addition, the inadequacy of personnel is partly to be attributed to the phenomena of brain drain, responsible for the migration of well-trained and experienced personnel in search of greener pastures. These factors hold back the progress of the country towards achieving the Vision 2030 targets and thus require urgent redress.

Sustainable peace and tranquility has eluded the region for a long time and conflict and civil strife has been seen to escalate in the last two decades with the fall of the Siad Barre regime in the former Republic of Somalia. The impact has been the proliferation of refugees and illegal fire-arms and ammunition into Kenya (Omosa, 2005; Mwenzwa & Njaramba, 2006) leading to a state of insecurity and thus affecting national development as investors are kept off. It is important that an atmosphere peace and tranquility is cultivated in the country first by securing international borders and secondly disarming pastoral communities and criminal gangs mainly in urban and some rural areas. Indeed, disarmament of the pastoral communities while the international borders remain porous is unlikely to achieve much. Failing to provide a safe haven for investment will erode investor confidence and thus render vision 2030 a mirage.

While planning is important for the achievement of development priorities and for ensuring sustainable wealth creation and hence poverty reduction, some of Kenya's development plans and targets are over- ambitious and unrealistic. For example, in the 1980s and early 1990s, the government promised to provide adequate tap water for every home by the year 2000. However, such a feat was not to be and it would seem that in 2000, taps that had running water in the 1980s had dried up, making Kenya a water scarce country (UNDP, 2008). In addition, in 1999, the government came up with an anti-poverty initiative, dubbed the National Poverty Eradication Plan (NPEP) 1999-2015 (Republic of Kenya, 1999) another yet over-ambitious plan given that even esteemed democracies of Western Europe and North America have yet to eradicate poverty among their citizenry. One would then be compelled to ask: is it really possible to *eradicate* poverty? Against this backdrop there is every reason to hypothesize that the Kenya Vision 2030 is yet another over-ambitious development blueprint!

Many areas of Kenya, particularly, ASALs experience perennial hunger, malnutrition and starvation due to the frequent yet predictable adverse weather patterns. As a result many people in the country cannot meet their basic needs of food, water and shelter. At the same time, there are vast pieces of land in agricultural potential areas that lie idle at the expense of food production. The government has recognized this problem and formulated the Kenya National Land Policy (Republic of Kenya, 2009). This policy has envisaged land reforms that would lead to prudent utilization of idle land to enhance national development. However, this may rise ``political temperatures`` given that the vast and yet idle land is the property of the *politico-economic elite.* It is important, therefore, that the land policy and the recently promulgated constitution are implemented to the letter to forestall hunger and associated problems in society. Only once the very basic needs of Kenyans are met can we think of achieving higher ideals as the targets in the Kenya Vision 2030.

In many areas of the country adverse weather conditions leave the areas devastated and therefore requiring humanitarian assistance. In much of arid and semi-arid areas, natural as well as human induced catastrophes have been seen to leave behind them a great trail of human suffering. This is

partly blamed on the absence of a viable Early Warning Systems (EWS) for major disasters. For example, floods and drought have been seen to occur within months of each other from year to year (UN, 2007). These events have the tendency to retard development and therefore seen as impediments to the achievement of the Vision 2030. It is imperative that viable disaster EWSs are developed and personnel deployed in disaster-prone areas to ward off their consequences.

Financial indiscipline is not strange to Kenya and it would seem that corruption has been institutionalized to the detriment of development and the welfare of Kenyan citizenry (Mulei, 2000).From land scandals to Goldenberg, Anglo Leasing scandal and political mischief, Kenya has lost substantial resources that would otherwise be invested in the provision of social services such as education, security, health and water that are glaringly unmet. This is compounded by government red tape regarding access to social services, considerably disillusioning the tax payer. These are significant impediments to the achievement of Vision 2030 proposals and hence the need to tackle them decisively. It is important that such vices and their breeding grounds are effectively dismantled and those culpable in both the public and private sector made to face the law as a deterrence to others.

References

Republic of Kenya (2003). Economic Recovery Strategy for Wealth and Employment Creation (2003 - 2007) Nairobi: Government Printer.

Republic of Kenya (2006). Mid – Term Review of the Economic Recovery Strategy for Wealth and Employment Creation. Nairobi: Government Printer.

Republic of Kenya (2008). First Medium Term Plan 2008 – 2010 Kenya Vision 2030.

KIPPRA (2009). Kenya *E*conomic Report 2009. Nairobi, KIPPRA.

Republic of Kenya (2003). Effective Management for Sustainable Economic Growth and Poverty Eradication 2006 Nairobi, Government Printer.

Bujra, A. P. and Keriga, L. (2009). Social Policy, Development and Governance in Kenya: A profile on Heath Care Provision in Kenya. Nairobi Developmentpolicy Management Forum.

Ministry of Health (2005). Reversing the trends: The National Health sector strategy Plan: NHSSP - 11:2005-2010: Nairobi: Ministry of Health.

Kimalu, P. K, Nafule N. N. and Mondo D. K. (2004). A review of the Health sector in Kenya. Kenya institute of public policy research and analysis: KIPPRA working paper No. 11 2004.

Kanyinga, K. (2001). Leadership and Governance in Post – Colonial Africa In Bahemuka, J.M and J. l. Brockington. East Africa in transition: Communities, Cultures and Change. Acton publishers, Nairobi .

Misati, A. J. and Mwenzwa E. M. (2010). Kenya's Social Development Proposals and Challenges: A review of Kenya vision 2030 First medium Term plan. 2008-2012. Unpublished Research Report.

Republic of Kenya (2002). National Development plan 2002 – 2008. Effective Management for Sustainable Growth and Poverty Reduction Nairobi. Government printer.

Republic of Kenya (2010). The proposed constitution of Kenya. Attorney General's Chambers. Nairobi.

THE ROLE OF QUALITY IN GROWTH OF SMALL AND MEDIUM ENTERPRISES AND ECONOMIC DEVELOPMENT IN KENYA

K. L. Wanjau, R. W. Gakure and J. Kahiri
Department of Entreprenuership and Procurement, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail:k_wanjau@yahoo.com

Abstract
The purpose of this paper was to evaluate the contributions of quality initiatives towards growth and industrialization of manufacturing small and medium enterprises (SMEs) in Kenya. Quality has been recognized as a successful management philosophy in the manufacturing industry. The study adopted an exploratory approach using a descriptive survey. The instruments of the study were a questionnaire, interview schedule (structured) and an observation checklist. In this study, 123 manufacturing SMEs were extensively surveyed, to ascertain contributions made by quality initiatives in the manufacturing sector towards realizing growth and industrialization. The correlations between various quality implementation dimensions and growth have been evaluated and validated by employing various statistical tools. The findings revealed that quality has a positive influence on growth and industrialization of an organization and economic development in general. The overall results indicated that entrepreneurial management (EM), marketing orientation (MO) and capacity enhancement of employees had significant linear relationship with quality. Surprisingly, no statistical evidence was found to confirm the effect of investing in technology and adoption of quality. The study recommended that SMEs must create a culture that is conducive to and supportive of quality implementation. They must align quality implementation with their goals and competitive environment. Government and other organizations supporting entrepreneurship development could assist and train manufacturing SMEs to acquire appropriate technology. This will go a long way in assisting SMEs in initiating quality practices supported by technology. Findings of the present study may assist public policy – makers and entrepreneurs to evaluate the importance of quality in enhancing SME growth, which serve as the best potential source of job creation and industrialization of the Kenyan economy.

Key words: Quality, SMEs, manufacturing enterprises, ISO, consultant, enterprise growth, economic growth, plant

1.0 Introduction

Small and medium manufacturing enterprises in Kenya's manufacturing sector are defined as enterprises with full-time employees not exceeding 100 or annual sales turnover not exceeding Ksh 150 million. The development of competitive and resilient small and medium enterprises (SMEs) forms an integral component of Kenya's initiatives to be globally competitive and prosperous nation with a high quality of life by 2030 (GoK, 2007).

The challenges posed by increased liberalization, new entrants to the market, increased standards requirements and technological developments require SMEs to raise efficiency levels, strengthen inter-firm linkages and respond timely to market changes. At the same time, greater integration into the global economy provides opportunities for SMEs to participate in the international value chain and supply chains networks. This will enable SMEs to move up the value chain and adopt new technologies, particularly information and communication technology (ICT). Only SMEs that are capable of harnessing technology and knowledge to develop high value-added products of superior quality will be able to compete globally (GoK, 2007).

It is clear that quality has emerged as a strategic competitive tool for organizational success (Yong and Wilknson, 2002). In today's business environment, organizations cannot afford to ignore the strategic implications of quality for its competitive position (Rohitratana & Boon-Itt, 2001).

Both large and small, production and service, and public and private organizations have made commitments to quality initiatives like total quality management (TQM) by making it fundamental to their growth (Oakland, 2004). Increasing product quality results in higher profits because costs are decreased and productivity and market share are improved (Ryan, Deane & Ellington, 2001; Gupta, 2004).

The relevance of formal quality management initiatives such as Total Quality Management (TQM), quality certification, and Quality Awards to small and medium enterprises (SMEs) has been a highly contentious issue in the quality and SME literatures over the past decade. Besides the ubiquitous criticisms of these initiatives based on the prohibitive costs of implementation, increased bureaucracy and complexity, and managerial confusion over the different methods, there is little evidence to support their pecuniary rewards to SMEs (Husband and Mandal, 1999).

Internationally, empirical research into the rate and success of implementation of these initiatives in SMEs is largely considered to be inadequate Literature in this area is more often conceptual than empirical, and where empirical, it sometimes suffers from methodological limitations (such as unclear or inconsistent definitions of what constitutes an SME) (Ramsey 1998; Kuratko, Goodale and Hornsby, 2001). Of the limited research available, it appears that SMEs have been very slow to implement formal quality models, and where they have, the outcomes are inconclusive (Husband and Mandal, 1999).

1.1 The Problem

Although small companies tend to be creative and innovative, they generally lag behind larger firms when it comes to adoption of quality (McMahon, 2001). Studies by Elmati and Kathawala (1999) indicate that the adoption of quality by small businesses has been minimal. The initial emphasis for a long time has been measuring the success of a business in relation to mass production. Research has confirmed the strategic benefits of quality programs and better quality is proven to contribute to greater market share and return on investment (Cole, 1992; Phillips, Chang and Buzzell, 1983), lower manufacturing costs; improve productivity (Garvin, 1988) and improve the area of strategic performance (Zhang, 2000).

Despite the above cited benefits, SMEs have been somewhat slow in adopting quality initiatives, not only due to excessive managerial involvement in day-to-day entrepreneurial activities that typically focus on sales strategies and market growth but also because they are less comfortable with the formal approaches that have been advocated as part of ISO 9000 series registration, and introduction of quality initiatives like TQM (Yusof and Aspinwall, 1999; McTeer andDale, 1994). Despite its conceptual rigor, the role of quality in affecting organizational growth or performance (whether facilitative or causative) particularly within the context of small businesses requires research attention (Tatoglu and Zaim, 2006).

Research shows that most SMEs loose between 5%-15% of sales revenue as a result of the lack of attention to quality (McMahon, 2001). This suggests that formal quality management systems are important tools contributing to the growth and development of SMEs. This study aimed to address the gap in research on the relationship between quality initiatives and SME growth in Kenya. In order to bridge the gap and provide SMEs with practical assistance in dealing with this issue, this research used a sample of manufacturing SMEs within Kenya to examine whether adoption of quality inevitably contribute towards growth of the firm and the economy.

1.2 General Objective

The study investigated the role of quality in growth of SMEs in Kenya.

1.2.1 Specific Objectives

In order to fulfill general objectives, this study intended:

(i) To investigate whether adoption of quality in SMEs influences entrepreneurial management**.**
(ii) To investigate whether adoption of quality in SMEs influences market- orientation.
(iii) To determine whether Small and Medium Enterprises in the manufacturing sector have the employee capacity to introduce and ensure adoption of quality.
(iv) To investigate whether adoption of quality influences investment in technology (plant).
(v) To determine whether the independent factors (EM, MO, capacity of employees and investment in technology) together influence adoption of quality.

1.3 Research Hypotheses

To examine how each of the criterion variables influences the response variable, the following null hypotheses were tested:

H_1: There is no relationship between entrepreneurial management (EM) and adoption of quality in SMEs.

H_2: There is no relationship between market orientation (MO) and adoption of quality in SMEs.

H_3: The capacity of employees is not related to adoption to quality in SMEs.

H_4: There is no relationship between investment in technology and adoption of quality in SMEs.

H_5**:** There is no relationship between adoption of quality and growth in SMEs.

H_6: The independent factors (EM, MO, capacity of employees and investment in technology) together do not influence adoption of quality.

1.4 Justification

Since Small and Medium Enterprises dominate the industrial scene in most developing countries, a deeper understanding of quality and why adoption of quality is important, may make it possible to pursue industrialization, thereby leading to results that are more equitable and efficient. Quality is a key strategy for maintaining competitive advantage and is a way of managing firms to improve its overall effectiveness and performance towards achieving world- class status (Zhang, Waszink and Wijngaard, 2000, Chapman and Al-Khawaldeh, 2002).

The only way a developing nation can increase its trade activities and develop sustainable basis is to improve the quality of its product and services. Developing countries, particularly the emerging ones, are blessed with a big advantage. They do not have to make the mistakes and omissions that were made by industrialized countries, because they can move into the proper position if they take time to study the trends. In an increasingly competitive world, quality is no longer an optional extra; it is an essential strategy for all firms regardless of size and location (Agus, 2000).

Research pointing to the effectiveness (or otherwise) of quality initiatives in SMEs is important to the continued development and competitiveness of small and medium enterprises. The growing interest in adoption of quality has led to the emergence of a distinct stream of quality research. Although a number of researchers and academicians have extensively examined quality implementation practices in industrialized countries such as the United States of America, Japan, the United Kingdom and other European countries, it is only recent years that a few researchers have begun to examine quality practices in developing countries. Of the few studies in developing countries, the majority has examined quality practices of large firms. Thus, studies on adoption of quality practices by SMEs in developing countries, particularly in Africa, are few (Magd, 2008).

It is relevant to note that, although a significant part of its industrial structure is mainly dominated by SMEs, few studies address the analysis of quality implications within smaller countries (Pinto, 2008). In line with Bayati and Taghavi (2007), there is a need for research on adoption of quality by SMEs in specific geographical regions. Kenya seems to be an interesting case given the significant role that SMEs play in the economic sector and due to the fact that it has a more advanced economy in comparison with other East African countries. To date, research interest in the role of quality in SMEs in general, and manufacturing SMEs in particular, is surprisingly sparse and underdeveloped (Weinzimmer, 2000). There is limited research literature to date on the adoption of quality by SMEs in Kenya.

2.0 Literature Review

The study examined the role of quality in growth of small and medium enterprises in Kenya. In this section, the study explores the role of quality in SMEs as articulated by various scholars and the research gaps they identified .The study focuses on both theoretical and past studies on the topic. A conceptual framework has also been developed.

2.1 Concept of Quality

Deming (1986) considered quality and process improvement activities as the catalyst necessary to start an economic chain reaction. Improving quality leads to decreased costs, fewer mistakes, fewer delays, and better use of resources, which in turn leads to improved productivity, which enables a firm to capture more of the market, which enables the firm to stay in business, which results in providing more jobs (Summers, 2006).

The quality concept has been a popular research topic in marketing and management literature where researchers have attempted to identify key dimensions of quality initiatives and performance. Researchers have defined the concept of quality in different ways ranging from perception of value (Summers, 2006) to conformance to requirements (Deming, 1986), fitness to use (Juran, 1979) and finally to meeting customer's expectations (Oakland, 2004). Quality is a customer determination based on the customer's actual experience with the product or service, measured against his or her requirements stated or unstated, conscious or merely sensed, technically operational or entirely subjective and always representing a moving target in a competitive market (Cole, 2002). Gupta (2004) point out the importance of quality by saying "quality is an important strategic dimension and a key competitive weapon that cannot be ignored by any corporation."

2.2 Overview of the Kenya Manufacturing Sector

The growing competition in the market place, the advance of manufacturing technologies, and shorter product life cycles has exerted strong impacts on the entire manufacturing industry. Under such a dynamic environment, small and medium enterprises (SMEs) have deployed various approaches to reposition their competitive priorities such as cost, quality and delivery so as to achieve the ultimate goal to customer satisfaction (Chen, 1999). The Kenyan economy has remained predominantly agro- based since independence, with the manufacturing sector remaining an integral part of the country's development strategies.

The manufacturing sector is an important source of employment for the country's labour force and currently employs about 2.7 million Kenyans in 2007 with micro, small and medium enterprises (MSMEs) share in employment having expanded rapidly in recent years. Over the last 5 years, employment in manufacturing has grown at a rate faster than in all other activities. The sector's real value added grew by 6.2% in 2007 compared to 6.3% in 2006. Total value output rose to Ksh 603.7 billion in 2007 from Ksh 558.3 billion in 2006 representing an 8.1% growth (GoK, 2008).

Since 2003 the sector has shown improved growth resulting from enhanced power supply, increased market opportunities within the East African Community (EAC) and the Common Market for Eastern and Southern Africa (COMESA), favorable tax reforms and other incentives. Sub-sectors which recorded growth were meat and dairy products, canned vegetables, fruits, fish, oils, fats; beverages and tobacco; petroleum and other chemicals among others. The significant growth recorded in key sub-sectors was mainly due to the opening up of new processing plants, diversification of products, increased capacity utilization and a construction boom leading to increased regional trade especially for firms exporting manufactured goods. Growth in business investment on the other hand led to increased output in manufacturing hence contributing to the overall economy.

2.3 Conceptual Framework

In a conceptual framework, descriptive categories are systematically placed in a broad structure of explicit propositions, statements of relationships between two or more empirical properties to be accepted or rejected (Parsons & Shils, 1962). It comprises of independent variables and dependent variables.

This study adopted a conceptual framework of strategic importance to identify some underlying forces behind different aspects of the key concept of quality. In particular, it investigated the significance of entrepreneurship management (namely risk taking and innovations), market orientation; capacity enhancement and technology (see figure.2.0). According to Wolff and Pett (2006) within SME research, the issue of firm growth/ performance has taken a place of prominence as a dependent variable.

Figure 2.0 below depicts the relationship between different constructs that are of paramount importance for achieving long-term sustainable competitive advantage.

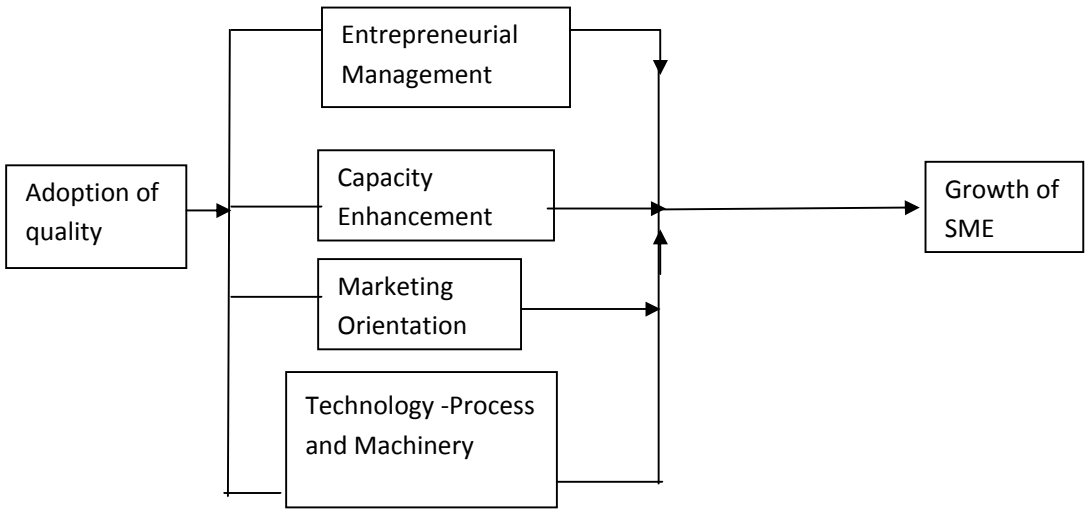


Figure 2: Conceptual Framework

2.3.1 Relationship between Entrepreneurial Management and Adoption of Quality

Entrepreneurship contributes significantly to the economy (Ahire, Walter and Golhar 1995). Schumpeter (1961) simply defines the entrepreneur as the one who brings about innovations which is what creates real development in the economy. Without the entrepreneur the economy would grow (too) slowly. The entrepreneur creates 'revolutionary' expansions in the economy by creating new combinations of existing resources, such as new products, new production methods or new markets, new sources of supply of raw materials and semi manufactured products and development of new organizations (Schumpeter, 1961). The entrepreneurial function or role is thus defined by its disproportional contribution to the economy. Or in other words, an entrepreneur is one who contributes significantly more than others to the economy by virtue of creativity and realizing new combinations.

Entrepreneurial management is a management style that involves a set of organizational processes, methods and styles used by an enterprise to act entrepreneurially (Jarillo & Stevenson, 1990). Entrepreneurial management consists of managerial training, quality objective setting, commitment to quality, systematic business planning and vision, and actively championing communicating quality issues. The implementation of product quality in SMEs revolves around the role and responsibilities of the manager/owner. The success or otherwise of implementing quality initiatives like TQM is often down to the owner/manager of the business who constitutes the driving force behind adoption of quality (van der Weile and Brown, 1998; Warnack, 2003).

The firm's owner/manager can encourage quality in the design process by sheltering the design function from pressures to rush new products to market before they have been thoroughly tested (Hammer, 2001). The entrepreneur influences work attitudes through the development and communication of a clear strategy that identifies the nature and direction of the organization as including quality performance, thus, encouraging goal congruency (Spilling, 2001). The entrepreneur or manager should accept his/her responsibility for adopting quality and provide active quality leadership, thus it is hypothesized:

Hypothesis 1: There is no relationship between entrepreneurial management and adoption of quality by small and medium enterprise.

2.3.2 Relationship between Market Orientation and Adoption of Quality

Market orientation (MO) is perceived as a system of corporate beliefs and values pivoting around; (1) the creation of superior customer value at a profit while not neglecting the interest of other key stakeholders, (2) the shaping of the company's internal environment and climate so that the company can be responsive to market information (Forker, 1997). On these grounds, it can be inferred that market orientation is an organizational culture that places the customer in the centre of the strategies or even at the top of the company's considerations. Ho (1999a) admits this cultural dimension when finding that the company's top management beliefs have a catalytic role as to whether the firm pursues a market orientation or not.

Quality of products has become an important aspect of competitiveness and a key market access concern in the export markets (Burke and Jarhatt, 2004). Consumers are increasingly demanding International Standards Organizations (ISO) Certification since they act as signals for quality, health and safety, and environment best practices (GoK 2007). Value creation for customers calls for close co-ordination between marketing and quality departments (Slater and Narver, 1995). Both quality implementation and market orientation require an organizational structure to be designed around the flow of value-adding activities and should also empower employees to manage organizational change. Given the information oriented nature of quality practices and market oriented firm, quality implementation may offer a rich array of tools that organizations could be transformed in achieving market orientation. Based on these and other supporting arguments we hypothesize that:

Hypothesis 2: There is no relationship between marketing orientation and adoption of quality in SMEs.

2.3.3 Relationship between Capacity Building and Enhancement of Employees and Adoption of Quality

Capacity building and enhancement consist of training and education, participation in decision-making, suggestion systems, incentive mechanisms and work autonomy (Temtime and Solomon, 2002). Capacity effectively translates into the knowledge of what to do and how to do it, and the capability to transform that knowledge into effective decisions and actions to solve development problems for both the short and long-term (Slack and Lewis, 2002). Employee empowerment is effective in SMEs where most frequently the customer's perception of quality stands or falls based on the action of the employee in one-on-one relationship with customer (Temtime and Solomon, 2002). In recent years, the emphases on human issues and involvement of employees have increased within the field of quality (Cruickshank, 2000).

The goal of the organization is to develop a useful quality system and employees are involved in developing the procedures and work instructions that can prepare the way for further progress down the quality maturity path. When employees are loyal to the firm and have pride in being part of it, they will be more willing to take individual risks in order to better the firm. Small and medium enterprises put only average emphasis on the importance of employee empowerment and involvement in quality implementation (Temtime & Solomon, 2002), thus it's hypothesized:

Hypothesis 3: There is no relationship between adoptions of quality and enhancing employee capacity in SMEs**.**

2.3.4 Relationship between Investment in Technology and Adoption of Quality

Technology is a broad concept that deals with a species' usage and knowledge of tools and crafts, and how it affects a species' ability to control and adapt to its environment. In human society, it is a consequence of science and engineering, although several technological advances predate the two concepts (Stoneman and Diederen, 1994). In order to achieve and maintain competitiveness in the international market, small and medium enterprise manufacturers must embrace modern

technologies that enable them develop efficient production (Greenway, 1994). Maintaining consistent quality of products and reducing human content are major factors affecting a firm's decision to upgrade manufacturing technology.

Advanced manufacturing technology can improve quality throughout the entire manufacturing process in areas such as materials handling, inventory control and production planning and scheduling. Advanced systems lead to quality improvements in the design stage because errors are discovered earlier in the process and more quickly. This allows adjustments to be made much faster and more accurately than without advanced manufacturing technology, helping to ensure quality in the manufacturing process (Ariss, Raghunathan and Kunnathar, 2000). Its adoption by small manufacturers gives them advantages over traditional manufacturing systems, such as lower cost quality improvements, higher productivity, and less working capital tied up in inventory (Phillips & Ledgerwood, 1994).

Technology is mainly concerned with production automation, flexible manufacturing and advanced processing equipment. Technology contributes to the competitive advantages of product quality, flexibility and low cost (Chen, 1999). Studies have shown that Kenya's small and medium enterprise manufacturers are applying relatively old technology compared to its neighbors. SMEs in Kenya are finding it difficult to access the local and export market due to poor production techniques (GoK, 2007). Most of the plants and machinery is sourced from Europe and Asia. Increasing value addition in the entire production chain is imperative if Kenya is to achieve industrialization (GoK, 2007).

Hypothesis 4: There is no relationship between investment in technology and adoption of quality in small and medium enterprises.

2.3.5 Relationship between Quality Adoption and Growth in Small and Medium Enterprises

The ever increasing intensity of market competition has made the implementation of quality practices, a prerequisite for a firm's survival. In comparing larger firms with smaller firms, Hendricks and Singhal (2001) argue that smaller firms tend to benefit more from quality initiatives like TQM as compared to larger firms. This argument contradicts with some of the earlier arguments on the role of quality initiatives in SMEs (that quality initiatives are less beneficial to smaller firms).

As quality improves, so does cost, resulting in improved market share and hence profitability and growth. Improving both internal (conformance) quality and external (customer perceived) quality not only lowers cost of poor quality or "non-quality" but also serves as a driver for growth, market share and profitability. In addition to profitability and market share, quality drives growth (Oakland, 1989).

Hypothesis 5: There is no relationship between adoption of quality and growth in small and medium enterprise.

3.0 Methodology

The study adopted an exploratory approach using a descriptive survey design, which ensured ease in understanding the insight and ideas about the problem. It aimed to investigate five objectives and testing of five hypotheses formulated from the review of the literature. In this study, descriptive survey design was used to obtain information from a sample of 123 respondents and for testing hypotheses on adoption of quality by SMEs. Descriptive survey design is flexible enough to provide opportunity for considering different aspects of a problem under study (Kothari, 2004). This design was further appropriate for this study since Borg, Gall & Gall (2003) note that descriptive survey research is intended to produce statistical information about the aspects of the research issue (in this case quality) that may interest policy makers and SME entrepreneurs.

3.1 Target Population of the Study

The study focused on manufacturing SMEs in Nairobi and its selected environs namely Ruiru, Athi River and Limuru. This is because manufacturing SMEs in Nairobi and its environs have formal procedures or processes that are documented and registered with regulatory government bodies (Gok, 2007).According to Ministry of Industrialization 2005 data base, 2,120 manufacturing SMEs are registered as formal enterprises. 1,258 manufacturing SMEs are located in Nairobi and its selected environs. This number (1,258) was further divided into sub-sectors, using International Standard Industrial Classification. The sub-sectors are agro-based, chemical and mining and finally engineering and construction. According to the Ministry of Industrialization, 582 enterprises are in the agro-based sub sector, 300 enterprises are in the chemical and mining sub-sector and 354 enterprises are in the engineering and construction sub-sector all based in Nairobi and its selected environs.

3.2 Sampling Technique

The type of manufacturing industry was used as a parameter for stratification to select the SMEs to be included in each stratum. With ideal stratification, each stratum is homogeneous internally and heterogeneous with other strata (Cooper & Schindler, 2003).This criterion required SMEs only involved in manufacturing products and classified using International Standard Industrial Classification, which was used as a stratification factor together with the number of employees.

3.3 Sample Size

Using proportional allocation, 58 agro-based, 30 chemical and mining and 35 engineering and construction enterprises were visited. Stratification is also called for when different methods of data collection are applied in different parts of the population. The ideal stratification was based on the primary variable under study, that is, adoption of quality (Cooper & Schindler, 2003).

3.4 Research Instruments

A self-administered questionnaire, face-to-face standardized interview schedules, and observation were the three principal research instruments of data collection. Primary data was collected using these three tools. An observation checklist provided a reliable and valid account of what was happening in various SMEs. The questionnaire was structured to according to the specific objectives that are entrepreneurial management, technology, market orientation and capacity enhancement and building.

3.5 Pilot Testing

To ascertain the validity and reliability of questionnaire, interview and observation schedules a pre-test and pilot survey was conducted. The purpose of pilot testing was to establish the accuracy and appropriateness of the research design and instrumentation and to provide proxy data for selection of a probability sample (Saunders, Lewis, & Thornhill, 2007).

3.6 Data Analysis

The data obtained from the three research instruments was analyzed by use of descriptive statistics (frequencies and percentages) and inferential statistics. Descriptive statistics in form of frequencies, means and standard deviations were utilized to analyze data obtained from the SME observations schedule (pre-test and post-test results). Analysis of variance (ANOVA) was used to analyse the degree of relationship between the variables in the study (for example the relationship between entrepreneurial management and adoption of quality). This indicated the strength and direction of association between the variables.

The multiple regression analyses determined whether the group of factors proposed together predicted adoption of quality which would also influence growth. The analysis was done using the

SPSS computer program to generate the t- value. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was undertaken (Magd, 2008).

4.0 Research Findings and Discussion

4.1 Response Rate

A total of 123 organizations were surveyed to ascertain contributions made by quality initiatives towards realization of growth and responded. This resulted into 100% responses rate.

4.2 Hypothesis Testing

The purpose of hypothesis testing is to determine the accuracy of the study hypotheses due to the fact that the researcher has collected a sample of data, not a census (Cooper & Schindler, 2003). In hypothesis testing the main question is: whether to accept the null hypothesis or not to accept the null hypothesis (Kothari, 2004).

Hypothesis 1*:* There is no relationship between entrepreneurial management and adoption of quality in small and medium enterprise.

To test this hypothesis, which had the null hypothesis that there is no linear relationship between the two variables a linear regression F-test was carried out. Analysis of Variance (ANOVA) was used to determine whether there is a regression relationship, between entrepreneurial management (EM) and adoption of quality in SMEs. The F-test results were, F= 5.037, and 121 degrees of freedom, and the critical values for F-test (1, 120, at 0.05 alpha is 1.2255) which is less than the computed F-value, then we reject the null hypothesis and conclude that there is a linear relationship between the variable entrepreneurial management and adoption of quality in SMEs.

The findings are in support of other research studies that indicate that entrepreneurial management has positive influence on the adoption of quality initiatives in SMEs. As many firms have discovered that the key to customer satisfaction and competitive success lies in emphasizing and achieving product and service quality as a strategic weapon in performing business (Pulat, 1994; Krasachol and Guh, 2001; Reed, Lemak, and Mero, 1999).

Hypothesis 2: There is no relationship between marketing orientation and adoption of quality in small and medium enterprises.

To test this hypothesis, linear regression F-test which had the null hypothesis that there is no linear relationship between the two variables was carried out. The linear regression F-test results were F = 1.56, and 121 degrees of freedom, and the critical values for F-test (1, 120,at 0.05 alpha is 1.2255) which is less than the computed F-value , then we reject the null hypothesis and conclude that there is a linear relationship between the market orientation and adoption of quality in SMEs.

The results of the hypothesis indicate that there is a relationship between MO and adoption of quality initiatives in SMEs studied. This supports the definition of market orientation as advanced by Mandal (2000), who postulated that definition of market orientation shares some common dimensions of quality initiatives philosophies. Day (1994) in his study confirms this relationship between market orientation and adoption of quality initiative like TQM, but warns that the weakness in adoption of quality to achieve market orientation is that the effectiveness of quality practices is internally contained and a repetitive process which may not go beyond the bounds of the organization.

Hypothesis 3: There is no relationship between adoption of quality and capacity of employees in small and medium enterprises

To test this hypothesis, linear regression F-test which had the null hypothesis that there is no linear relationship between the two variables was carried out. The F-test results were, F= 3.75, and 121

degrees of freedom, and the critical values for F-test (1, 121,at 0.05 alpha is 1.2255) which is less than the computed F-value , then we reject the null hypothesis and conclude that there is a linear relationship between the adoption of quality and capacity of employees in SMEs. These findings confirm other studies that show that employee involvement in implementing quality initiatives is critical for its successful implementation.

Studies show that employees' involvement in quality initiatives like ISO 9000:2000 has increased (Cruickshank, 2000). Research in basic quality initiative implementation argues that for successful quality implementation, soft aspects such as; teamwork, extensive training, high level of communication, employee involvement, empowerment and organizational culture must be observed. Employee empowerment is effective in SMEs where most frequently the customer's perception of quality stands or falls based on the action of the employee in one-on-one relationship with customer (Temtime & Solomon, 2002).

Hypothesis 4: There is no relationship between investment in technology and adoption of quality in small and medium enterprises

To test hypothesis, linear regression F-test which had the null hypothesis that there is no linear relationship between investment in technology and adoption of quality in SMEs was carried out. The linear regression F-test results were, F= 0.68, and 121 degrees of freedom, and the critical values for F-test (1, 121, at 0.05 alpha is 1.2255) is more than the computed F-value, then we accept the null hypothesis and conclude that there is no linear relationship between the investment in technology and adoption of quality in SMEs. The rejection of this hypothesis is a reverse of past studies by Philips and Ledgerwood (1994); Zairi, (1993); Scott-Morton, (1991); Ariss, Raghunathan and Kunnathar (2000) who had stated small firms could adopt technologies to gain significant advantages over their competitors.

The study results may be explained by the fact that manufacturing SMEs may not quickly adopt new technology despite consulting a quality inspection firm, because of largely having "traditional" owners or managers (Schroeder, Gopinath and Congden, 1989), who exhibit a fear of technology, which may cause them to create a barrier to the adoption of advanced manufacturing technology.

Hypothesis 5: There is no relationship between adoption of quality and growth in small and medium enterprises.

To establish the strength and the direction of the relationship between adoption of quality programs and growth in firms studied, rankings were made of the various aspects of growth based on whether a firm had adopted any quality initiatives. The study then utilized the Spearman's rho coefficient to indicate the strength and direction of the relationship between adoption of quality and growth in SMEs. The study established that there exists a moderately positive correlation (r = + 0 .379) between the quality programs and growth of firms studied. Therefore, the null hypothesis was rejected and study confirmed that there is a relationship between growth and adoption of quality initiatives in SMEs.

The findings empirically support the notion that SMEs with a higher quality commitment for example ISO 9000, do obtain increased results. These results confirm studies done by previous researchers in this area such as (Douglas and Judge, 2001). Kaynak (2003) also reports a similar correlation between quality initiatives implementation and the perceptual measures of growth. Also Samson and Terziovski (1999) and Dow, Samson and Ford (1999) conducted research in Australia and New Zealand and found a significant relationship between quality management practices and organizational growth/performance.

5.0 Summary, Conclusions and Recommendations

5.1 Summary

Aspects of entrepreneurial management had been influenced by adoption of quality programs. The entrepreneurial orientation and time spent on quality improvement programs were found to have relatively strong influence on the adoption of quality programs by SMEs studied, while benchmarked against, measures by Kittler, Mernard and Phillips, (2007). The study concludes that the entrepreneur/manager influences work attitudes through the development and communication of a clear strategy that identifies the nature and direction of the organization as including quality performance, thus, encouraging goal congruency (Douglas and Judge, 2001). The active involvement, attention, and direction of the entrepreneur is crucial in assuring firm- wide quality adoption.

The study established that marketing orientation (MO) and adoption of quality programs of the SMEs studied was found to be statistically significant at 5% level, indicating a liner model relationship between MO and adoption of quality. As many firms have discovered that the key to customer satisfaction and competitive success lies in emphasizing and achieving product and service quality as a strategic weapon in performing business (Pulat, 1994; Krasachol and Guh, 2001; Reed, Lemak and Mero, 1999).

The study established that adoption of quality has an influence on the capacity of employees. The study supports the arguments that in order to be fully successful and self sustaining, adoption of quality initiatives like TQM requires an extensive refashioning of 'softer' practices (Schonberger, 1994; Dale et al., 1994) whose elements consist of essentially dimensions of human resources management (Dale *et al.,* 1994).

The study established that there is no linear relationship between the investment in technology and adoption of quality in SMEs studied. Smaller firms may lack sufficient financial and human resources required for the implementation of some technological processes, resulting in lower levels of adoption of more costly technologies (Cagliano & Spina, 2002). Studies have shown that Kenya's small and medium enterprise manufacturers are applying relatively old technology compared to its neighbors. SMEs in Kenya are finding it difficult to access the local and export market due to poor production techniques (GoK, 2007).
The study established the significance of adoption quality programs on growth of the firms studied. The findings support findings by Kaynak (2003) who reports a similar correlation between quality initiative implementation and the perceptual measures of growth.

5.2 Conclusion

While there is no single type of strategy, which was associated with growth, the best performing SMEs in the study were those, which were the most active along a number of dimensions while being particularly active in managing their products and markets. In this respect, the study confirms with other research findings that the success of quality adoption appeared to rely more on executive commitment, open organization and employee empowerment rather than on benchmarks and process improvement. This study confirms the direct relationship between quality practices and organizational growth.

5.3 Recommendations

The study recommends institutional managers for both local and foreign, non-governmental organizations (NGOs), funding agencies and the government should assist and train manufacturing SMEs to acquire appropriate technology. The study also recommends that a decision criteria for selecting quality approaches need to be identified, and a rational decision aid framework needs to be developed to assist entrepreneurs of small and medium enterprises when they want to adopt to various quality initiatives.

The study also recommends organizations like Kenya Bureau of Standards (KEBS) that run quality inspection programs for manufacturing firms, should restructure their programs to include quality management practices and its implementation in SMEs. The study finally

References

Agus, A. (2000). TQM practices in manufacturing companies in Malaysia: *An Exploratory Total Quality Management*, **11**(8), pp 104-51.

Ahire, S., Waller, M. and Golhar, D. Y. (1995). Quality management in TQM firms: An empirical study. *International Journal of Quality and Reliability Management*, **13**, pp 8-27.

Ariss, S. S., Raghunathan, T. S. and Kunnather, A. (2000). Factors affecting the adoption of advanced manufacturing technology in small firms. *S.A.M. Advanced Management Journal,* **65**(2), 14.

Bayati, A. and Taghavi, A. (2007). The impacts of acquiring ISO 9000 certification on the performance of SMEs in Tehran. *TQM Magazine,* **19**(2).

Borg, W. R., Gall, M. D. and Gall, J. P. (2003). Educational Research: An Introduction. (6th edn). New York: Longman Inc.

Burke, G. I. and Jarhatt, D. G. (2004). The influence of information and advice on competitive strategy definition in small and medium sized enterprises. *Qualitative Market Research: An International Journal*, **7**(2), pp 126-38.

Cagliano, R. and Spina, G. (2002). A comparison of practice-performance models between small manufacturers and sub contractors. *International Journal of Operations* & *Production Management,* **22**(12), pp 1367-1388.

Chapman, R. and Al-Khawaldeh, K. (2002). Quality management worldwide: TQM and labour productivity in Jordanian industrial companies. *The TQM Magazine*, **14** (4), pp 248-62.

Cole, R.E. (2002). *Personnel and Human Resource Management.* (5th edn.). London: Biddles Ltd.

Cooper, R. D. and Schindler, P. S. (2003). Business Research Methods. (8th edn.) New Delhi: Tata McGraw-Hill Edition.

Cruickshank, M. T. (2000). *Developing a Quality Culture within a School of Nursing in Higher Education*. Unpublished doctoral dissertation, University of Western Sydney, Hawkesbury, Australia.

Dale, B. G., Boarden, R. J. and Lascelles, D. M. (1994).Total quality management: An overview in Dale, B.G.(Ed) *Managing Quality*. (2nd edn.). London: Prentice-Hall pp. 1-40.

Day, G. S. (1994). The capabilities of market driven organization. *Journal of Marketing*, **58**, pp 37-52.

Deming, W. E. (1986). Out of the Crisis. MA. Massachusetts Institute of Technology, Center for Advanced Engineering.

Douglas, T. J. and Judge, W. Q. Jr. (2001). The quality management implementation and competitive advantage: The role of structural control and exploration. *Academy of Management Journal*, **44**(1), pp 158-69.

Elimuti, D. and Kathawala, Y. (1999). Small services firms face implementing challenges. *Quality Progress*, **32**(4), pp 67.

Forker, L. B. (1997). Factors affecting supplier quality performance. *Journal of Operations Management,* **15**, pp 243-69.

Greenway, D. (1994). The diffusion of new technology. *The Economic Journal,* **104**, pp 916-17.

Gupta, P. (2004). Six Sigma Business Scorecard. New York: McGraw-Hill

Hendricks, K. B. and Singhal, V. R. (2001). The long–run stock price performance of firms with effective TQM programs. *Management Science,* **47**(3), pp 359-368.

Husband, S. and Mandal, P. (1999). Perceptions and realities of quality methods in Australian small to medium sized enterprises. *Proceedings of the 12th Annual SEAANZ Conference, 6-8 May 1999* (pp143-157). Melbourne, Victoria, Australia: Victoria University of Technology.

Jarillo, J. C. and Stevenson, H. H. (1990). A paradigm of entrepreneurship: Entrepreneurial management. *Strategic Management Journal,* **11**, pp 17-27.

Juran, J. M. (1979). Quality Control Handbook. London: McGraw-Hill.

Kaynak, H. (2003). The relationship between total quality management practices and their effects on firm performance. *Journal of Operations Management*, **21**, pp 405-435.

Kittler, J. E., Menard, W. and Phillips, K.A. (2007). Weight concerns in individuals with body dysmorphic disorder. *Eating Behaviours*, **8**, pp 115–120.

Kothari, C. R. (2004). Research Methodology; Methods and Techniques. New Delhi: New Age International (P) Ltd. Publishers.

Krasachol, L. and Guh, E. (2001). Quality management in developing countries. Integrated Management: Proceedings of the 6th International Conference on ISO 9000 and TQM, 17-19 April 2001 (pp.299-304). Paisley, United Kingdom: University of Paisley.

Kuratko, D. F., Goodale, J. C. and Hornsby, J. S. (2001). Quality practice for a competitive advantage in smaller firms. *Journal of Small Business Management,* **39**(4), pp 293-311.

Magd, H. A. E. (2008). ISO 9001: 2000 in the Egyptian manufacturing sector: Perceptions and perspectives. *International Journal of Quality and Reliability Management,* **25**(2), pp 173-200.

Mandal, P. (2000). Interfunctional spread of quality in manufacturing. *Industrial Management & Data Systems*, **100**(3), pp 135-140.

McMahon, R. G. P. (2001). Deriving empirical development taxonomy for manufacturing SMEs using data from Australia's Business Longitudinal Survey. *Small Business Economics*, **17**(3), pp 197 – 212.

McTeer, M. M. and Dale, B. G. (1994). Are the ISO 9000 series of quality management systems standards of value to small companies? *European Journal of Purchasing and Supply Management*, **1**(4), pp 227-35.

Oakland, J. S. (1989). Total Quality Management. London: Elsevier Butterworth-Heinemann Publications.

Oakland, J. S. (2004). Quality Management. London: Elsevier Butterworth-Heinemann Publications.

Parsons, T. and Shils, E. A. (1962). *Towards a General Theory of Action.* New York: Harper and Row, pp 50-51.

Phillips, T. E. and Leedgerwood, J. R. (1994). Running with the pack: JIT and automation for small manufacturers. *National Public Account*, **39**, pp 26-28.

Pinto, J. C. (2008). TQM and performance in small enterprises: The mediating effect of customer orientation and innovation. *International Journal of Quality and Reliability Management,* **25**(3), pp 256-275.

Pulat, B. M. (1994). Total quality management: A framework for application in manufacturing. *The TQM Magazine.* **6**(4), pp 44-49.

Ramsey, J. (1998). The value of ISO 9000 certification to a small business. Proceedings: Second International and Fifth National Research Conference on Quality Management. Pakistan. pp 145-156.

Reed, R., Lemak, J. D., and Mero, P. N. (1999). Total quality management and competitive advantage. *Journal of Quality,* **5**, pp 5-26.

Rohitratana, K. and Boon-Itt, S. (2001). The implementation of ISO 9000 in Thai Seafood Processing Industry: An empirical study. Integrated Management: Proceedings of the 6th International Conference on ISO 9000 and TQM, 17-19 April 2001 (pp. 477-482). Paisley, United Kingdom: University of Paisley.

Ryan, C. C., Deane, R. and Ellington, N. P. (2001). Quality management training in small to midsized manufacturing firms. *Quality Management Journal,* **8**(2), pp 44-52.

Saunders, M., Lewis, P. and Thornhill, A. (2007). Research Methods for Business Students. (4th edn.). Harlow: Financial Times Prentice Hall.

Schroeder, D. M., Gopinath, C., & Congden, S.W. (1989). New technology and small manufacturer: Panecea or plague? *Journal of Small Business Management,* **27**(3), pp 1-10.

Schumpeter, J. (1961). Capitalism, Socialism and Democracy. New York: Harper and Bros.

Scott-Morton M. (1991). *The Corporation of the 1990s: Information Technology and Organizational Transformation*. Oxford University Press.

Slack, N. and Lewis, M. (2002). Operations Strategy. Harlow: Financial Times Prentice Hall.

Slater, S. F. and Narver, J. C. (1995). Market orientation and the learning organization. *Journal of Marketing*, **59**, pp 63-74.

Stoneman, P. and Diederen, P. (1994). Technology diffusion and public policy. The Economic journal, **104**, pp 918-930.

Summers, D. C. S. (2006). *Quality*. New Jersey: Pearson Education Inc.

Tatoglu, E. and Zaim, S. (2006). TQM and market orientation's on SMEs performance. *Industrial Management and Data Systems,* **106**(8), pp 1206-1228.

Temtime, T. Z. and Solomon, G.H. (2002). Total management and the planning behaviour of SMEs in developing economies. *The TQM Magazine,* **14**(3), pp 181-191.

Weinzimmer, L. (2000). Replication and extension of organizational growth determinants. *Journal of Business Research,* **48**(1), pp 35-41.

Wolff, J. and Pett, T. (2006). Small-firm performance: Modeling the role of product and process improvements. *Journal of Small Business Management*, **44**(2), pp 268-284.

Yong, J. and Wilkinson, A. (2002). The long and winding road: The evolution of quality management. *Total Quality Management,* **13**(1), pp 101-121.

Yusof, S. M. and Aspinwall, E. (1999). Critical success factors for total quality management implementation in small and medium enterprises. *Total Quality Management*, 10, S803-S809.

Zairi, M. (1993). Competitive manufacturing: combining total quality management with advanced technology. *Long Range Planning,* **26**(3), pp123-132.

Zhang Z. H., Waszink A. B. and Wijngaard, J. (2000). An instrument for measuring TQM Implementation for Chinese manufacturing companies. *International Journal of Quality and Reliability Management*, **17**(7), pp 730-

INFLUENCE OF POWER DISTANCE ON EMPLOYEE EMPOWERMENT AND MULTINATIONAL CORPORATION PERFORMANCE IN KENYA

M. A. Oloko
Commerce and Economics Studies, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: olokomargaret@yahoo.com

Abstract
A study was carried out with the specific objectives as to establish the influence of power distance on the strength of the relationship between employee empowerment and organization performance and to establish whether there is a direct relationship between employee empowerment and organization performance. Data for the study was collected using a questionnaire which contained measurements of power distance, employee empowerment and non-financial measures of performance of organizations. A pilot study was conducted to pre-test the questionnaire using a sample of 10 respondents. The questionnaire consisted of a Likert type scale ranging from 5 – very great extent to 1 – not at all. A census study of 60 multinational corporations operating in Kenya was conducted. The response rate was 65%, which is, 39 firms were interviewed. These results confirmed that the strength of the relationship between employee empowerment and MNC performance in a host country is influenced by power distance. The result ($r = 0.608$, < 0.01) showed a moderate relationship between employee empowerment and MNC performance. The magnitude of the correlation coefficient implies a moderate relationship ($r = 0643$, $p < 0.01$) between employee empowerment and organization performance.

Key words: Employee empowerment, power distance and multinational corporation performance (MNC)

1.0 Introduction

1.1 Background of the Study

Today, multinational corporations (MNCs) are increasingly conducting their business globally, which has increased in scope due to the increasing complexity as the companies operate across national, cultural and social boundaries. The greatest challenge facing the corporations is to acknowledge the cultural differences in every host country and to manage the business cohesively in order to achieve corporate objectives and enhance MNC performance. Current literature indicates that culture is an important determinant of organizational performance in host countries. This is because for success of business operations, MNCs have to understand the prevailing culture (power distance) in each of the host countries they operate in (Hofstede, 1983; Blunt and Jones, 1986; Kuada, 1994; Newman and Nollen, 1996).

In any organization, power distance influences the amount of formal hierarchy, the degree of centralization, the amount of participation in decision-making and the performance level. According to Hofstede (1984), culture varies from one country to another resulting in MNC performance variations hence, the need to understand its effect on host countries and thus, include it in the empowerment - performance equation.

Many researchers in this area of study have only concentrated on the importance of empowerment practice in facilitating organizational performance (Argyris, 1998; Eylon and Au, 1999 and Robert et al. 2000). That is, to them empowerment is the perfect panacea for success in organizations. However, some researchers report that there has to be congruence between the management practices (like empowerment) of foreign firms and the cultural practices in the specific host countries (Kaloki, 2001; Tihanyi *et al*., 2005). This study attempts to establish the influence of power distance on the relationship between employee empowerment practice and MNC performance

According to Hofstede (1984), power distance is the extent to which a society accepts an unequal distribution of power in institutions or organizations within a hierarchy. The researcher divided his study on power distance into two, namely; high (countries in Latin America, Asia and Africa) and low (countries like the United States of America, Germany, Great Britain, Canada, France, Belgium, e.t.c.) power distance. Hofstede reported that subordinates in a high-power distance culture are highly dependent on their superiors for direction and further suggested that employees manage their work according to what the managers stipulate (respect for hierarchy). In this case, the employees are more co-operative dealing with the superiors and are, frightened of disagreeing with them, but are reluctant to cooperate with their peers.

Therefore, employees of multinational corporations operating under high power distance country culture may not feel comfortable making decisions that had previously been made by their superiors. That is, they may be slower to take on greater problem- solving and decision-making responsibility. The workers in such a culture will expect their supervisors to control information, provide clear boundaries, make decisions and tell them what to do. This results in low levels of employee empowerment and in turn likely to lead to low organizational performance.

According to Vogt and Murrell (1997), employee empowerment (empowerment of individuals, groups, organizations and societies) is a noble, necessary and natural part of human development for the success of multinational corporations' operation throughout the world. The researchers further reported that employee empowerment is a technique to enable, to allow or to permit, that which, can be perceived as both self-initiated and initiated by others. That is, the process of empowerment enlarges the power in a situation as opposed to merely re-distributing it.

Randolph (2000) referred to employee empowerment as a means of transferring appropriate and sufficient authority to employees and making resources available to enable them succeed in their jobs, providing them with a conducive environment and proper tools to enable them contribute to the organizational performance at a higher level. The researcher reported that management must help employees achieve these goals by coaching; teaching and enabling them to acquire the right skills for effective performance. He further suggested that this process is an interactive process based on a synergistic assumption about power. Employee empowerment can also refer to an act of building, developing and increasing power through cooperation, sharing and working together or giving the employees the discretion to make decisions regarding their own tasks and responsibility within an organization (Randolph *et al*., 2002).

Today, performance of MNCs has become a dominant research theme, and a growing number of research studies consider empowerment practice as paramount in organizations; an important predictor of performance (Argyris, 1998; Luo and Peng, 1999; Eylon and Au, 1999; Robert *et al.*, 2000). The researchers reported that for organizations to increase their performance in a global environment, they need to empower their employees to make faster decisions within the organizations.

The researches that have been advanced in this area show that employee empowerment may directly lead to organizational performance and this notion has been supported by many researchers like, Eylon and Au (1999), Robert and colleagues (2000) and Randolph and colleagues (2002) who conducted studies on empowerment and performance and concluded that, when employees are empowered, organizational productivity increases, thus leading to an increase in MNC performance. But, the link between employee empowerment practice and MNC performance is not likely to be direct, especially in countries that experience high power distance cultures, like Kenya and other countries from the developing world. This is because performance of an organization depends, to a great extent, on the outcomes of empowerment practice (such as organizational commitment, job autonomy and job satisfaction), which may be favourable or unfavourable. For example, if empowerment outcomes are unfavourable resulting in low organizational commitment, low job autonomy and low job satisfaction on the part of employees, then MNC performance will be unfavourable or low in a host country.

In a high power distance culture, employee empowerment is low, and the organizational performance is likely to be low. To this extent, employees in a high power distance culture show a high level of dependence on their superiors for direction within the organization, and a multinational corporation is likely to experience low performance.

On the other hand, a multinational firm operating in a low power distance country culture is likely to rely on high employee empowerment. This is because the job factors may be favourable leading to high organizational performance since the employees are willing to use their discretion in decision-making to achieve higher goals. But, in some instances, high employee empowerment may not lead to high organizational performance, especially if the right employee skills and equipments are not put in place.

Hofstede's (1983) research on intercultural management defines dimensions of differences in value orientations that affect the work of MNCs in different cultural settings, in terms of power distance, collectivism/individualism, masculinity/femininity and uncertainty avoidance. Of interest to this study is the dimension of power distance in which Hofstede found Latin America, Asia and Africa to have higher scores while those of Anglo - Saxons and Scandinavians were lower. According to him, high power distance score indicates that the relationship between superiors and subordinates are unequal, with both sides accepting status and privileges as normal levels of authority. For example,

the French are fairly high on Hofstede's power distance scale (Appendix II), while North Americans rank much lower. Despite the fact that, the French carry out their management activities with some level of formality, the Americans are rather very casual, and symbols of the former need to show rank and the latter's tendency to downplay it. This means that the two countries have different cultural backgrounds, which affect their behaviour pattern thus different performance levels.

According to Hofstede (1980, 1983, 1984, 1997), countries in Africa (Kenya included) are classified as experiencing high power distance culture (Appendix III), which refers to the extent to which the less powerful members expect and accept that power is distributed unequally in the organization. For example, in high power distance culture countries, employee empowerment practice tends to be low and the outcomes tend to be low or unfavourable. This is because employees do not take initiatives in decision-making processes but wait upon the managers to define direction for them. That is, the techniques for employee empowerment in Kenya may be similar to those used elsewhere, but the difference would be in the extent of use.

Despite all this, there has been no study conducted to establish the influence of power distance on the relationship between employee empowerment and performance throughout the world and more so, for the less developed countries. For example, the few studies that have been carried out in Africa have only emphasized on the importance of empowerment or the congruence between the management practices and the cultural practices of the local firms. That is, for success of firms in host countries, the MNCs' management practices must be consistent with the countries' cultural background. Nzelibe (1986) reported that expatriate managers in Nigeria applied Western management practices and failed to consider the implications of the local cultures on their management practices, resulting in unfavourable performance level. The researcher concluded that local cultures play a key role in the success of MNCs and further added that local cultures call for adherence in MNC operations if they are to succeed especially in less developed countries.

Blunt and Jones (1986) study on organizational change in Africa, found little understanding of effects of local cultures on the part of foreign managers and that they did not consider this factor (local culture) in their operations, hence failed to consider its implications on their management practices, resulting in unfavourable performance. Kuada (1994) also concurred with Blunt and Jones (1986) when he conducted a study on managerial behaviour in Ghana and Kenya and found that there was no regard for local cultures. The researchers concluded that management practices by foreign firms should be consistent with national cultures in both Ghana and Kenya. Kaloki (2001) also carried out a research on MNCs and cultural beliefs in Kenya and still found disparity in the foreign firms' management practices and the local cultures. He concluded that MNCs should be able to understand the relationship between the employee behaviour and management practices if they are to succeed in their operations.

1.2 Statement of the Problem

Despite great emphasis laid on research in the field of employee empowerment and MNC performance throughout the world, there is inadequacy of literature on this subject especially in the developing countries and how organizational performance may be influenced by the prevailing host country culture. The existing literature has only focused on explaining the importance of employee empowerment in facilitating MNC performance particularly in the developed world (Denison and Mishra, 1995; Argyris, 1998; Eylon and Au, 1999 and Robert et al. 2000).

Empirical work on employee empowerment and MNC performance supports the assertion that organizations that make use of empowerment practice are likely to experience higher levels of performance than their counterparts who do not (Earley, 1994; Henart and Larimo, 1998; Robert, et al. 2000: Randolph et al. 2002). While this may be true, that the practice of empowerment increases

performance in organizations, most studies have ignored the influence of power distance on this relationship, yet culture influences the way activities are conducted in every host country thereby determining the performance level.

Most researches in this field have devoted much attention to studying the relationship between empowerment and MNC performance as if there were a direct link between them. But, the direct relationship may only be possible in countries where there is low power distance culture especially, in the developed world like, North America, Britain, Germany and Canada (Earley, 1994; Henart and Larimo, 1998; Robert et al. 2000; Randolph et al. 2002). It would also appear that given the high power distance culture in the developing countries, the management techniques like empowerment might not likely succeed because of the gap between the top management and the lower level employees in terms of decision-making. The departure of this study from previous ones to the current is the inclusion of culture as a moderating variable in the relationship between empowerment and organizational performance.

Objectives

To determine as to the nature or strength of the relationship between employee empowerment and performance of a multinational corporation is influenced by power distance and to establish whether there is a direct relationship between employee empowerment and multinational performance.

3.0 Materials and Methods

3.1 Research Design

This study used a cross-sectional research design that allowed the researcher to integrate empowerment research literature and the questionnaires as a main procedure to gather accurate, less bias data and increase the quality of data being collected (Cresswell, 1998; Sekaran, 2000). The interviews were conducted on employees (of the organizations under study) who hold management and non-management positions. Their opinions were sought about the nature of the relationships between the variables of interest namely, employee empowerment, and power distance and organizational performance. To determine the influence of power distance on the relationship between employee empowerment and MNC performance, multivariate analysis was used for the purposes of modeling the complex phenomena and relationships that exist between the variables.

This involved relating variables of study to find out the relationship amongst them. For the purposes of this study, the researcher established the link between employee empowerment and MNC performance as moderated by power distance in Kenya. Today, many scholars concur that employee empowerment leads to better MNC performance (Newman and Nollen, 1996, Argyris, 1998; Kaloki, 2001). But, this relationship cannot be considered in isolation. That is, the culture inherent in every host country will affect the operations of a multinational corporation positively or negatively.

3.2 Population of Study

The population of study comprised all employees working for the multinational corporations studied. A census technique was used since the number of multinational corporations in Kenya is fairly small. According to Hofstede (1980), this population was considered appropriate because it represented MNCs from both low and high power distance countries.

A list of MNCs operating in Kenya was obtained from the internet (2006) and was adjusted using a list from the Investment Promotion Council and the Nation Business Directory (2007). This yielded a total of 60 MNCs in Kenya, mainly foreign owned (Appendix II). Of these firms, 22 are from USA, 20 from UK, 6 from Japan, 2 from Switzerland, 3 from Germany, 2 from India, 1 from France, 1 from

Canada, 1 from South Korea, 1 from Finland, and 1 from Sweden. All these MNCs were studied regardless of how long they have operated in Kenya.

3.3 Sample Size

3.3.1 Sampling Design

The population of study comprised 60 multinational firms. Out of which, a sample size of 240 respondents from both high power and low power distance cultural backgrounds was requied. For every organization, the researcher sent out four (4) questionnaires to be filled by four (4) employees (managers and non-managers) in every organization to show their levels of involvement in organizational decision-making. Out of the 60 MNCs under study, 39 of them filled and returned the questionnaires. This represented a response rate of 65% of the study population.

A stratified random sampling technique was used to select the respondents from each of the multinational corporations. Based on the respondents' position in the organization – (viz., managers and non-managers). The managers were those at the higher and middle levels of the hierarchy, i.e., top, middle and lower level managers while non-managers were those at the lower levels and included supervisors, clerks and secretaries. The stratification also considered the gender issue. That is, an equitable number of men and women were drawn where possible.

The researcher then used simple random sampling technique to draw up respondents from each stratum based on their original predetermined population numbers. The method is considered appropriate because it provided information from all the categories of employees in the organization. This method of sampling has been used in the previous studies with little bias reported (Chui, 2002). Selection of respondents for this study was obtained through the common formula suggested by several scholars (Sekaran, 2002) as stated in equition 1.

$$\frac{n = z^2 x\ pq}{d^2} \quad \text{.....(1)}$$

where

n = the desired sample size (if the target population is greater than 10,000)

z = the degree of confidence which in this case was 95% confidence interval

p = stands for the population having the characteristic to be measured (there being no reasonable estimate of p = 50% or p = 0.5 was adopted to maximize the expected variance and ensure that the sample was large enough)

q = 1 – p (this stands for the population not having the characteristic which in his case was 0.5)

d = stands for the degree of accuracy required (in this case was set at 5%)

Since the target population for this study was less than 10,000, then a smaller sample size could be used without affecting the accuracy and this required an adjusted minimum sample size to be calculated as follows:

$$\frac{n' = n}{1 + [n/N]} \quad \text{.....(2)}$$

Where,

n' = the adjusted minimum sample size

n = is the minimum sample size already calculated above

N = is the total population

3.4 Data Acquisition

Primary data which covered information on employee empowerment and empowerment outcomes, host country culture, and non-financial measures of performance was collected. The non-financial measures included variables such as customer satisfaction, commitment to work, product reliability, faster decision-making processes, choice, impact, meaningfulness and power inequality. To ensure face validity of responses, the questionnaires were administered to the respondents through personal interviews, and where this was not applicable, the researcher used drop and pick method. Telephone interviews and personal visits were used as follow-ups.

A questionnaire (Appendix I) was used to collect primary data. It contained both structured and unstructured questions, and was divided into three parts. Part A asked questions about national culture (power distance and the extent to which power is distributed equally or unequally in organizations. Part B, asked questions about employee empowerment. A Likert scale ranging from 5-denoting to a great extent to 1-denoting not at all was used. The respondents were requested to rate the given statements that characterized their behaviour and attitudes towards the organization's level of employee empowerment. Finally, Part C asked questions about the perception of MNC performance. It required the respondents to rate the performance of their organizations in terms of non-financial measures (using perceptual measures like, product quality, customer satisfaction, and product reliability, response to customer needs, employee creativity and speed of decision-making). A 5 - point Likert scale showed the extent to which the employees agreed with the statements given, that ranged from 5 - denoting to a very great extent to 1 - denoting not at all.

The questionnaire was pre-tested with a sample of respondents in order to establish whether the questions therein measure the expected theorized variables in the conceptual framework at the end of the literature review. A pilot study on a few selected respondents was conducted to ascertain the clarity of the questions. The respondents were also asked to comment on the clarity and the amount of time it would take to fill one questionnaire. The final questionnaire was then adjusted on the basis of the findings of the pilot test and a final version was developed for study. The research assistants were deployed to conduct personal interviews to collect the data from the respondents.

3.5 Reliability and Validity

Reliability attests to the consistency and stability of the measuring instrument. The common internal consistency measure is the Cronbach's Alpha, given as in equation 3.

$$\alpha = \frac{N - r}{1 + (N - 1).\, r} \quad \text{.....(3)}$$

Where;

N = the number of components or items being tested

α = the extent to which a set of test items can be treated as measuring a single variable

r = the average of all correlation coefficients

Reliability does not however imply validity because while a reliable measure is measuring something consistently, it may not necessarily be what is supposed to be measuring. Therefore, test validity is prerequisite to test reliability because test validity is required before reliability can be considered meaningful in any way.

The instrument testing reliability used different numbers of scale items. That is, the study investigated the reliability of the independent (employee empowerment), the dependent (organizational performance and the moderating (power distance) variables. Cronbach's alpha was used to test the consistency of items in the scalesIn this case, power distance was measured using 30

items, employee empowerment was measured using 17 items, and organizational performance was measured using 20 items. According to Nunully and Bernestein, 1994) a reliable variable should produce an alpha coefficient of 0.700 and above. Employee empowerment was used as the independent variable, power distance as the moderating variable and organizational performance as the dependent variable.

Validity is a mechanism that ensures that process implemented to collect data has collected the intended data accurately. That is, it refers to the extent to which an empirical measure adequately reflects the real meaning of the variable under investigated. In this study, validity of the measurement instruments was established using expert judgement. That is, a group of knowledgeable and experienced researchers examined the instruments and confirmed that they appeared capable of measuring what they were designed to measure.

4.0 Results and Discussion

The reliability of the instrument was tested and yielded correlation coefficients scores for employee empowerment, power distance and non-financial measures of performance as 0.700, 0.790 and 0.875 respectively as shown in Table 1.

Table 1: Results of tests of reliability

Variable	Statements Measuring the Variables	Reliability (Cronbach's Alpha)
Employee empowerment	20	0.933
Power Distance	30	0.700
Non-financial Measures	17	0.875

4.1 Descriptive Statistics

Table 2 shows the mean, standard deviation and the Pearson correlations for the variables under study. The mean values of each variable ranges between 3.01 and 4.03, indicating that the level of employee empowerment and empowerment outcomes (organization commitment, job autonomy and job satisfaction) are high. The correlation coefficients between the independent variable (employee empowerment, empowerment outcomes), the moderating variable (power distance), and the dependent variable organization performance were less than 0.90, indicating the data are not affected by a serious co-linearity problem (Hair *et al*., 1998). These correlations also provided further evidence of validity and reliability for measurement scales used in this research.

Table 2: Descriptive statistics and Pearson correlations

Variables	Mean	Std. Dev	Power distance (Culture)	Employee empowerment
Power distance (Culture)	3.0119	.29504	1	
Employee empowerment	3.8031	.49601	-.026	1
Organizational performance	3.7710	.39905	.199(*)	.530(**)

** Correlation is significant at $p < 0.01$ (2-tailed), N = 160

* Correlation is significant at the $p < 0.05$ level (2-tailed), N = 160

The results indicate that power distance variable has a mean score of 3.012; this implies that the selected firms on average have moderate power distance. Employee empowerment variable has a mean score of 3.803 which implies that the firms practice employee empowerment to a great extent while organization commitment is at 3.590 also implying commitment to a moderate extent. Job autonomy was also present to a great extent with a mean score of 4.026 while job satisfaction had a mean score of 3.446.

4.2.1 Relationship between Employee Empowerment and MNC Performance as Moderated by Power Distance

Table 3 shows the relationship between employee empowerment (independent variable) and MNC performance (dependent variable). The table indicates that employee empowerment determines 36.9 per cent ($R^2 = 0.369$, $p < 0.01$) of the variation in the dependent variable which is significant at 0.05. Although the model did not explain a larger proportion of the variation in MNC performance, the data showed a moderately good fit ($r = 0.608$, $p < 0.01$) relationship between the independent and the dependent variable. It appears that 63.1 percent of variations are not explained by the factors in the study. According to Guilford's interpretative model, $r = 0.608$ shows a moderate correlation, remarkable or substantial relationship between employee empowerment and MNC performance.

Table 3: Regression Analysis for the relationship between Empowerment and MNC Performance

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate	Change in F Ratio				
					Change in R^2	F Change	df1	df2	Sig. of Change in F
1	.530(a)	.281	.276	.33954	.281	61.623	1	158	.000
2	.608(b)	.369	.361	.31897	.089	22.026	1	157	.000

Dependent variable: MNC performance

To examine the moderating effect of power distance on the relationship between employee empowerment and MNC performance, the researcher used a moderated multiple regression to establish the interaction effects. To achieve this, it was assumed that variable Z (Power distance) is the moderating variable between X (employee empowerment) and Y (MNC performance) and that this relationship depends on the value of Z. In this case, it involved a regression equation that included Y as a criterion variable and X and Z as predictor variables. It also included a third predictor variable consisting of Z*X (a product term) which explains the moderating effect of power distance (Z) on the relationship between employee empowerment and MNC performance. This is consistent with the suggestion by Aquins and Pierce (1999).

After entering the proposed main effects into the equation, the multiplicative terms were added. The regression weights for the multiplicative terms were then examined for significance. Table 5 showed that there is a significant relationship between MNC performance ($\beta = 1.974$, $p < 0.01$) and the interaction term, suggesting that performance increases by 21 percent for every unit change in employee empowerment. This implies that power distance moderates the relationship between employee empowerment and MNC performance as show in Table 4.

Table 4: Influence of Power Distance on the relationship between Empowerment and MNC Performance

Model	Variables	Std. Error	Standardized Coefficients (Beta)	t
1	(Constant)	0.208	2.150	10.328
	Employee Empowerment	0.054	0.530	7.850
2	(Constant)	0.199	1.974	9.910
	Employee Empowerment	0.055	0.404	5.868
	Power Distance of Parent Company	0.067	0.323	4.693

Dependent Variable: MNC performance
Significant at 0.05 levels

The results of the moderated multiple regression analysis support hypothesis 1 that power distance influences the relationship between employee empowerment and MNC performance where the standardized regression coefficient for the product term which carries information about the interac on between employee empowerment and MNC performance is not equal to 0 (i.e. $\beta \neq 0$) but is equal to 0.404 which is significant at $p < 0.01$. This indicates the presence of a moderating or interaction effect and is consistent with the interpretation made by Cohen & Cohen (1983). These results confirm hypothesis 1 that the strength of the relationship between employee empowerment and MNC performance in a host country is influenced by power distance. This leads to the conclusion that power distance moderates the relationship between employee empowerment and organiza onal performance ($\beta \neq 0$). This demonstrates that the strength of the rela onship between the two variables has been affected by power distance.

According to the results of the test of hypothesis 1 ($r = 0.608$, < 0.01), there is a moderate relationship between employee empowerment and MNC performance. Therefore hypothesis 1, r^2 (0.369) gives the amount of variance in the dependent (MNC performance) variable explained by the independent variable (employee empowerment). This implies that there is 36.9% variation in MNC performance explained by employee empowerment variable. It further explains that 63.1 percent of the variations in MNC performance are not explained by the model.

4.3.2 Relationship between Employee Empowerment and MNC Performance

Hypothesis 2 tested the direct relationship between employee empowerment and MNC performance. Pearson correlation analysis was used to test this hypothesis. The results in table 6 show that empowerment and performance are related. That is, employee empowerment is related to firm performance. The magnitude of the correlation coefficient implies a moderate relationship ($r = 0643$, $p < 0.01$) between employee empowerment and firm performance as shown in the table.

Table 5 indicates that in low power distance cultures, the correlation coefficient score for the relationship between employee empowerment and MNC performance is higher ($r = 0.643$, < 0.01) than in high power distance cultures ($r = 0.366$, $p < 0.01$).

Table 5: Power distance and relationship between empowerment and MNC performance

Power distance of Parent company	Variables	Employee empowerment	Organizational performance
Low	Employee empowerment	1	.643(**)
	Organizational performance	.643(**)	1
High	Employee empowerment	1	.366(**)
	Organizational performance	.366(**)	1

** Correlation is significant at $p < 0.01$ level (2-tailed) H: n = 34: L: n = 126

This conforms to literature where researchers like Argyris (1998), Eylon and Au (1999) and Robert et al. (2000) reported that employee empowerment is higher when the management practices of a firm are consistent with the local cultures. The results of this analysis is consistent with literature that employee empowerment leads to higher firm performance. But when power distance is high then the MNC performance will be lower ($r = 0.366$) as suggested in Table 6.

From the analysis, the researcher can conclude that employee empowerment leads to favourable MNC performance. This is only possible in countries that experience low power distance cultures (Western countries). It is evident that a host country culture will likely affect firm performance in a foreign country. Therefore firms operating in different cultural backgrounds must adhere to the cultural practices inherent in these countries. Despite this difference, employee empowerment has been found to be crucial in the success of firms. And that is, whether in high or low power distance cultures, the empowerment practice remains crucial.

References

Argyris, C. (1998). Empowerment: The Emperor's New Clothes," *Harvard Business Review*, Vol. **76**.

Blunt, P. and Jones, M. (1986). "Managerial Motivation in Kenya; A cross-cultural Comparison," *Journal of African Studies*, Vol. **24(**1).

Bowen, D. E. and Lawler, E. E. (1995). Empowering Service Employees," *Sloan Management Review*, Vol. **36**(4).

Chiu, C. K. W. (2002). Do Types of Economic Ownership Matter in Getting Employees to Commit? An exploratory study, In the Peoples Republic of China," *International Journal of HRM*, Vol. **13(**6).

Cohen, J. (1983). Work Commitment in Relation to withdrawal Intentions and Union Effectiveness," *Journal of Business Research,* Vol. **26**.

Conger, J. A. and Kanungo, R. N. (1988). The Empowerment Process: Integrating Theory and Practice, *Academy of Management Review*, Vol. **13**.

Cresswell, J. W., (1998). Qualitative inquiry and research design: Choosing among Five traditions, London: SAGE Publications.

Denison, D. R. and Mishra, K. (1995). Towards a History of Organizational culture and Effectiveness, *Organizational Science,* Vol. **6**.

Earley, P.C. (1994). Self or Group? Cultural Effects of Training on Self-Efficacy and Performance, *Administrative Science Quarterly*, Vol. **39**.

Eylon, D. and Au, K. Y. (1999). Exploring Empowering Cross-Cultural Differences along the Power Dimension, *International Journal of Inter-cultural Relations*, Vol. **23**.

Gomez-Mejia, L.R. and Palich, L.E. (1997). Cultural Diversity and the Performance of Multinational Firms, *Journal of International Business Studies*, Vol**. 28**.

Hardy, C. and Leiba-O'Sullivan, S. (1998). The Power Behind Empowerment: Implications for research and Application," *Human Relations*, Vol. **51**.

Hennart, J. F. and Larimo, J. (1998). Impact of Culture on the strategy of the Multinational Enterprise; Does national Origin Affect Ownership Decisions? *Journal of International, Business Studies*, Vol. **29**(3).

Hofstede, G. (1980). Culture's Consequences: International Differences in Work-Related Values, Sage Publications, Thousand Oaks, California.

Hopson, B. and Scally, U. (1981). *Life Skills Teaching*, Mc Graw-Hill, College Division, New York.

Hui, M. K., Au, K. and Fock, H. (2004). "Empowerment Effect Across Cultures, *Journal of International Business Studies,* Vol. **35**(1).

Kaloki, P. K. K. (2001). Job Satisfaction as a Function of Cultural Beliefs, Expectations and Goals: A Study of Employees of Foreign-owned Firms in Kenya: Unpublished Doctoral Thesis, Faculty of Commerce, University of Nairobi.

Kuada, J. E. (1994). Managerial Behaviour in Ghana and Kenya: A Cultural Perspective.

Lawler, E. (1992). The Ultimate Advantage, Jossey – Bass, San Francisco.

Li, J. and Guisinger, S. (1992). The Globalization of Service Multinational in the 'Triad' Regions: Japan, Western Europe and North America, *Journal of International Business Studies,* Vol. **23**.

Liden, R. C., Wayne, S. J. and Sparrowe, R. T. (2000). An examination of the Mediating Role of Psychological Empowerment on the Relations between the Job, Interpersonal Relations and the Work Outcomes, *Journal of Applied Psychology*, Vol. **83**(3).

Luo, Y. and Peng, M.W. (1999). Learning to compete in A Transition Economy: Experience, Environment, and Performance, *Journal of International Business Studies*, Vol. **30**.

Miller, D. L. (1994) "The Honourable Picnic: Doing Business in Japan, *Harvard Business Review*, Vol. **16**.

Newman, K. L. and Nollen, S. D. (1996). "Culture and Congruence. The Fit between Management Practices and National Culture," *Journal of International Business Studies,* Vol. **27**(4).

Nzelibe, C. (1986). The Evolution of African Management Thought, *International Studies of Management,* Vol. **16**(2).

Pfeffer, J. (1994). Competitive Advantage Through People, Boston, Harvard Business School Press.

Randolph, W. A. (2000). Re-Thinking Empowerment: Why is it so Hard to Achieve? *Organizational Dynamics*, Vol. **29**(2).

Randolph, W. A., Sashkin, and Marshall (2002). Can organizational Empowerment Work in Multi-National Settings? *Academy of Management Executives, February*, Vol. **16**.

Robert, C., Probst, T. M. Martocchio, J. J. Drasgow, F. and Lawler, J. J. (2000). Empowerment and Continuous Improvement in the United States, Mexico, Poland, and India: Predicting Fit on the Basis of dimensions of power distance and Individualism, *Journal of Applied Psychology,* Vol. **85**.

Sekaran, U., (2002). Research methods for business: A skill building approach. New York:
John Wiley and Sons, Inc.

Tihanyi, L., Griffith, D. A. and Russell, C. J. (2005). The Effect of Cultural Distance on Entry Mode Choice, International Diversification, and MNE Performance: A Meta-Analysis, *Journal of International Business Studies*, Vol. **36**, February.

Thomas, K. W. and Velthouse, B. A. (1990). Cognitive elements of Empowerment: An 'Interpretive' Model of Intrinsic Task Motivation," *Academy of Management Review*, Vol. **15**.

Tung, R. L. and Miller, L. (1990) "Managing in the 21st Century: The Need for Global Orientation," *Management International Review,* Vol. **30**.

Vogt, J. F. and Murrell, K. L. (1997). Empowerment in Organizations: How to Spark Exceptional Performance, S. Chand and Company Ltd., Ram Nagar, New Delhi.

Appendix 1: The Questionnaire

Enclosed is the questionnaire designed to collect data from firms operating in Kenya, especially those with foreign affiliations. Your firm has been chosen for study. The data will be used purely for academic purpose only, and will be treated with strict confidence. A confidential report will be availed to you at your request.

PART A: POWER DISTANCE OR HOST COUNTRY (NATIONAL) CULTURE

1. Indicate the extent to which you agree with the following statements in respect of power inequality in your organization (Indicate the appropriate numbers on the scale below).

Very Great Extent 5	Great Extent 4	Moderate Extent 3	Little Extent 2	Not at all 1
1. Employees have independence in executing their duties				_____
2. Managers do consult with the subordinates				_____
3. Top managers and lower cadre employees mix up freely in the organization				_____
4. Non-managers are free to take up positions different from that taken by managers				_____
5. Non- managers take initiatives in matters pertaining to their work				_____
6. Managers and non-managers hold joint meetings				_____
7. Non-managers have power and authority to execute their duties				_____
8. Power is equally distributed in the organization				_____
9. Non-managers disagree with the managers				_____
10. Non-managers trust each other				_____
11. Non-managers are allowed to participate in decision-making				_____
12. Non-managers are less afraid of disagreeing with their supervisors				_____
13. All should have equal rights in the organization				_____
14. Non-managers are much more cooperative				_____
15.Non-managers have a stronger perceived work ethics				_____
16. Non-managers are not allowed to make decisions on behalf of managers				_____
17. Non-managers have no authority and power				_____
18. Managers direct the non-managers on the way forward				_____
19. Non-managers are reluctant to trust each other				
20. Non-managers fear disagreeing with managers				_____
21. Power holders are entitled to privileges				_____
22. Powerful people should look more powerful				_____
23. Managers like seeing themselves as decision makers				_____
24. Non-managers place high value on conformity				_____
25. Cooperation among the powerless is difficult to bring about due to low faith in peoples' norms				_____
26. Non-managers do fear disagreeing with the supervisors				_____
27. There should be an order of inequality in this world.				_____
28. Managers make decisions autocratically				_____
29. Power is centralized in the organization				_____
30. Managers do not delegate important tasks to the non-managers				_____

PART B: EMPLOYEE EMPOWERMENT

2. To what extent do you agree or disagree that the following statements correctly characterize the behaviour and attitudes of employees in your organization (Respond to the items below indicating the appropriate number in the scale below, 1- denoting strong disagreement, and 5 - denoting strong agreement).

	Very Great Extent 5	Great Extent 4	Moderate Extent 3	Little Extent 2	Not at all 1
My organization,					
1. Encourages commitment					[ ]
2. Has holistic concern for employees					[ ]
3. Encourages open communication					[ ]
4. Increases cooperation, teamwork and support					[ ]
5. Encourages pro-active problem-solving					[ ]
6. Encourages work in a congenial and friendly atmosphere					[ ]
7. Encourages organization feedback					[ ]
8. Enhances meaning and value in a work task					[ ]
9. Increases employee Morale					[ ]
10. Increases employee job satisfaction					[ ]
11. Creates choice in task performance					[ ]
12. Allows for independent decision-making					[ ]
13. Allows choice and direction in one's work					[ ]
14. Instils confidence and belief in capacity to perform a task skilfully					[ ]
15. Inspires creativity and innovation					[ ]
16. Builds employee confidence in task performance					[ ]
17. Increases individual job autonomy					[ ]
18. Enhances employee's influence over organizational decisions					[ ]
19. Increases customer satisfaction					[ ]
20. Increases customer focus					[ ]

PART C: ORGANIZATIONAL PERFORMANCE
(Non-financial Measures of Performance)

3. Indicate the extent to which your organization exhibits the following characteristics regarding employee empowerment on MNC performance (Respond to each item using the scale below and indicate the response number on the line by each item.)

	Very Great Extent 5	Great Extent 4	Moderate Extent 3	Little Extent 2	Not at All 1
1. Satisfied customers					[ ]
2. Quick response to customer complaints					[ ]
3. Faster customer service					[ ]
4. Good organization image					[ ]
5. Increased output					[ ]

6. Quality products and services	[ ]
7. Product reliability	[ ]
8. Faster deliveries	[ ]
9. Faster decision-making processes	[ ]
10.Effective communication	[ ]
11.Ability to retain employees over a long period of time	[ ]
12. Good relationship between management and employees	[ ]
13.High market share as compared to other competitors	[ ]
14. Corporation's products are superior to competitors'	[ ]
15. Faster development of new products	[ ]
16. High involvement in research and development	[ ]
17. Employees are involved in task performance	[ ]

THANK YOU FOR YOUR TIME AND PATIENCE

Appendix ii: Mncs In Kenya
Company, Country of Origin and Company Product

Company	Country	Product
1. Air Express International	USA	Courier Services
2. AT & T	USA	Telecommunication
3. Agip	Italy	Petroleum Products
4. American Online	USA	Telecommunications
5. Bamburi Portland Cement	UK	Cement Manufacturing
6. BASF	Germany	Chemicals/Plastics
7. Barclays Bank	UK	Banking
8. BAT (K) Ltd	UK	Tobacco/Cigarettes
9. Bata (K) Ltd	Canada	Shoes
10. Bayer EA Ltd	Germany	Pharmaceuticals
11. Beta Health Care International Ltd	UK	Pharmaceuticals
12. British Airways	UK	Airline Services
13. British Oxygen	UK	Industrial Products
14. Cadbury Kenya	UK	Confectionery/Beverages
15. Caltex Oil	USA	Refinery Products
16. Celtel Kenya	UK	Telecommunication
17. Citi Bank NA	USA	Banking
18. Coca Cola	USA	Beverages
19. Colgate Palmolive	USA	Hygiene Products
20. Crown Paints (K) Ltd	UK	Manufacturing Paints
21. PZ Cussons (EA) Ltd	UK	Bathroom, Soap, Toiletries
22. Eveready Batteries (K) Ltd	USA	Dry Cell
23. Erickson	Sweden	Telecommunications
24. Yana Tyres	USA	Tyres
25. Fuji Kenya	Japan	Imaging
26. General Motors	USA	Vehicle Assembly
27. Glaxo/Smithkline	UK	Pharmaceuticals
28. Hilton Hotel	UK	Hotel
29. Hotel Intercontinental	USA	Hotel
30. IBM (EA) Ltd	USA	Computers
31. Intel Computers	USA	Computers
32. Johnson's Wax (EA) Ltd	USA	Detergents, prays, Perfumes
33. Kodak (EA) Ltd	UK	Imaging/Photography
34. Microsoft	USA	Software
35. Mitsubishi Corp	Japan	Motor vehicles
36. Mobil	USA	Petroleum Products
37. Nestle	Switzerland	Milk Products/ Beverages
38. New Stanley Hotel	USA	Hotel
39. Nokia	Finland	Telecommunications
40. Paper Mills	India	Paper Products
41. Philips International	USA	Electrical Appliances
42. Rank Xerox	USA	Office equipment
43. Safari Park Hotel	South Korea	Hotel
44 Shell/ BP	UK	Petroleum Products
45. Sara Lee	UK	Household & body Care

46. Siemens	Germany	Telecommunications
47. Standard Chartered Bank	UK	Banking
48. Sterling Products	USA	Soap, Baby Products/ Pharmaceutical
49. Sumitomo Corp.	Japan	Construction
50. Total Kenya	France	Petroleum Products
51. Toyota (EA) Ltd	Japan	Vehicle Assembly
52. Unilever	UK	Consumer Products/ tea/ Power Applications
53. Wrigley Company E.A Ltd	USA	Chewing Gum
54. Woollen Mills	India	Textiles
55. Procter & Allan	USA	Cereals
56. Gillette	USA	Personal Care
57. Reckitt & Benkiser (EA) Ltd	UK	Detergents
58. Safaricom	UK	Telecommunication
59. Sony	Japan	Electronics
60. Ayton Young and Rubicam	USA	Advertising

APPENDIX III: POWER DISTANCE INDEX

Power Distance Index (PDI) Value for 53 Countries in 3 Regions

Score Rank	Country or Origin	PDI Score
1	Malaysia	104
2/3	Panama	95
2/3	Guatemala	95
4	Philippines	94
5/6	Mexico	81
5/6	Venezuela	81
7	Arab Countries	80
8/9	Equador	78
8/9	Indonesia	78
10/11	India	77
10/11	West Africa	77
12	Yugoslavia	76
13	Singapore	74
14	Brazil	69
15/16	France	68
15/16	Hong Kong	68
17	Colombia	67
18/19	Salvador	66
18/19	Turkey	66
20	Belgium	67
21/23	East Africa	64
21/23	Peru	64
21/23	Thailand	64
24/25	Chile	63
24/25	Portugal	63
26	Uruguay	61
27/28	Greece	60
27/28	South Korea	60

29/30	Taiwan	58
29/30	Iran	58
31	Spain	57
32	Pakistan	55
33	Japan	54
34	Italy	50
35/36	Argentina	49
35/36	South Africa	49
37	Jamaica	45
38	USA	40
39	Canada	39
40	Netherlands	38
41	Australia	36
42/44	Costa Rica	35
42/44	Germany	35
42/44	Great Britain	35
45	Switzerland	34
46	Finland	33
47/48	Norway	31
47/48	Sweden	31
49	Ireland	28
50	New Zealand	22
51	Denmark	18
52	Israel	13
53	Austria	11

Source: Hofstede, G. (1997) Cultures and Organizations, Software of the Mind, Mc-Graw Hill, New York, P. 26.

Note: Numbers/positions ranging from 1-53 show the power inequality between low and high power distance cultures. Thus, the higher the Power Distance Index (PDI) Score, the higher the power distance.

UNDERSTANDING FINANCIAL DISTRESS AMONG LISTED FIRMS IN NAIROBI STOCK EXCHANGE: A QUANTITATIVE APPROACH USING THE Z-SCORE MULTI-DISCRIMINANT FINANCIAL ANALYSIS MODEL

F. G. Maina and M. M. Sakwa
Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: mfaithgathoni@gmail.com

ABSTRACT
The paper assesses the financial distress among listed firms in Nairobi Stock Exchange in Kenya. The Capital Market Authority (CMA) has a regulatory responsibility to keep surveillance of firms listed in Nairobi Stock Exchange (NSE) with regards to capital, liquidity and other aspects with overall aim of ensuring financial stability of these firms. The expectation is therefore that the firms will be financially prudent and healthy which in turn will attract investors. The recent crisis where a number of NSE listed companies' including stock brokers experienced financial distress is an indication that there is a missing link between surveillance and the management of these firms. If this is not rectified the public can loose interest in investing in Nairobi Stock Exchange. There is therefore a need to critically assess the financial position of the listed firms and suggest ways of improving the performance of NSE. This study utilizes the Z'-score multi-discriminant financial analysis model which provides the framework for gauging the financial performance of the firms. This is in addition to the use of the ANOVA and correlation tests in support of the evidences from the Z-score model. The sample constituted selected firms listed in Nairobi Stock Exchange divided into five different sectors. The results clearly indicated that the financial health of the listed companies needed to be improved. In addition a disjoint was noted in the correlation between what is expected of the listed companies in terms of financial performance and the benefits to be accrued from CMA surveillance on them. On the analysis of the financial statements of the listed firms it was postulated that the financial distress experienced by the firms are emanating from functioning of these firms. On the other hand, the Capital Market and NSE role responsibility needs to be strengthened. The study recommended that the NSE should make financial stability an integral driver
of its policy framework.

Key words: Financial distress, Governance and management, Capital Market Authority (CMA), Nairobi stock exchange, Z'-score multi-disriminant financial analysis model

1.0 Introdution

The importance of predicting financial distress has been increasing to corporate governance due to its severe effects on the operation of a firm, its environment (management, credit institutions, stockholders, investors, employees) and whole economy (Arnold, 2007). Evidence shows that the market value of the distressed firms declines substantially (Warner, 1977). Many managers focus on succeeding, at least in the short run, but there is much need to also focus on signals of distress, causes and its possible remedies before they reach a crisis (Harlan and Marjorie, 2002). Therefore, the use of an early warning system models is critically important to make a reliable measure of any company's financial health since companies that are strong today may not be strong tomorrow. Equally, many companies that are weak today will survive.

Financial distress is a broad concept that comprises several situations in which firms face some form of financial difficulty. The most common terms used to describe these situations are "bankruptcy,""failure," "insolvency," and "default." These terms provide a slightly different definition connected with the specific interest or condition of the firms under examination. Altman (1993) provided a complete description and definition of these terms. Bankruptcy identifies mostly with the legal definition of financial distress. As pointed out by Theodossiou et al. (1996), many financially distressed firms never file for bankruptcy, due to acquisition or privatization, whereas healthy firms often file for bankruptcy to avoid taxes and expensive lawsuits. Altman (1993) defines failure as the situation where "the realized rate of return on invested capital, with allowances for risk consideration, is significantly and continually lower than prevailing rates of similar investments." This is a term of an economic sense and does not indicate the discontinuity of a firm. Insolvency also illustrates a negative performance indicating liquidity problems. Insolvency in a bankruptcy sense indicates negative net worth. Finally, default refers to a situation where a firm violates a condition of an agreement with a creditor and can cause a legal action.

To overcome the differences among these situations, the more general term "financial distress" will be used throughout this article to describe the situation where a firm cannot pay its creditors, preferred stock shareholders, suppliers, etc., or the firm goes bankrupt according to the law. All these situations result in a discontinuity of the firm's operations, unless proper measures are employed.

Capital Markets Authority was established in 1989 through the Capital Markets Authority Act, Cap 485 A (the CMA Act) to regulate and oversee the orderly development of Kenya's capital markets. The Authority ensures the development and maintenance of an appropriate legal and regulatory framework to boost investor confidence, enhance efficiency and to create and maintain a fair and orderly market. The Authority also reviews existing policies and makes recommendations to the Government on new policy issues that could promote and enhance market development. It also provides guidance to market operators. Therefore, Capital Market Authority (CMA) has a regulatory responsibility to keep surveillance of firms listed in NSE with regards to capital, liquidity and other aspects with overall aim of ensuring financial stability of these firms.

The NSE has been operating for 50 years now, but has only been in real existence for 16 months now, in terms of capacity building. It failed to pick the growth momentum and currently the market has just about 58 listed firms which are less than what the country inherited at independent (Ngugi, Amanja and Maana, 2009). Nairobi Stock Exchange (NSE) has a double responsibility for development and regulation of the market operations to ensure efficient trading. For an efficient stock exchange, the companies listed in NSE are expected to be financially health so as to ensure economic growth of a country.

The motivation to undertake this study was provided following the many corporate failures in the Kenyan capital market and those have gone into receivership, only a handful of companies have managed to come of out of it in sound financial health. There is an increasing trend of failure of Kenyan firms such as KCC, Uchumi Supermarkets, A Baumann and Company, Bulk medical limited, Nyaga stock brokers are examples of these.

The NSE has been performing poorly in recent years. The performance of the stock market indicates that the market has not managed to make significant contribution to financing economic growth (Ngugi, Amanja and Maana, 2009). While there are about 58 companies listed in NSE, not all of them are in a financially sound position. Although at the point of listing, these listed companies must meet the listing requirement of NSE, given time, the company's financial position and business direction can change for the better or for the worse. There are many reasons for these changes, such as governance, management, financial appetite, risk profile or over gearing. Therefore surveillance in the market is necessary to ensure efficient trading.
However, some listed companies seem to be able to survive and therefore the question remains why some are performing poorly while others are failing. This appear that NSE and CMA are abrogating their mandate to instill discipline in the market players and to protect investors' funds as evidenced in collapse of many stockbrokerage firms. This can result in the loss of investors' confidence in the capital market and in turn equity market becoming outperformed by other markets such as real estate market.

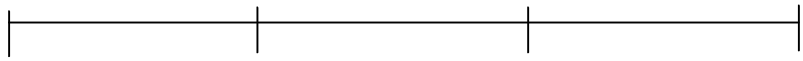
Looking at the above situation and looking at the importance of Kenyan economy, understanding financial distress of listed firms in NSE is important to investors so that, early actions could be taken as a precaution. This study utilizes the Z'-score multi-discriminant financial analysis model which provides the framework for gauging the financial structure of the firms. This is in addition to the use of the ANOVA and correlation tests to support the evidences from the Z-score model. Although these traditional techniques or models do not provide much guidance on how they should be applied to emerging market, the models have already been empirically tested in emerging markets and used with good results (Pereiro, 2006).

The purpose of this study is therefore not to test the model but use it as a tool in measuring financial distress status of the companies selected for this analysis. The results for each company can then be studied further by analysing the results of each variable in order to identify why the score is in the distress zone or the non-distress zone. Therefore, the aim of the study is to survey the financial distress status of listed firms in NSE and to map out their financial performance trend using the Z'-score model in order to come up with several important policy implications.

The paper is organized into five sections. The following section offers literature review as a discussion on previous studies. Section three provides the explanation of the data and research methodology used to answer the objectives of this study. The fourth section presents the results and a discussion or the research findings coming from Z'-score, ANOVA and correlations. The final section provides conclusions of the study, its implications and suggestions for future research.

2.0 Financial Distress Models

The models of financial distress are commonly referred to as bankruptcy prediction models. Financial health of a firm might be viewed along a continuum (Stickney, 1996) as follows:



Financially Healthy | Financially Troubled | Bankrupt | Liquidated

Previous bankruptcy research had identified many ratios that were important in predicting bankruptcy. Among the most popular financial ratios used by researchers were; Beaver (1966) estimated a univariate financial distress model. Altman (1968) analyzed the financial distress problem of a firm by employing a multiple discriminant analysis (MDA), Matin (1977) and Ohlson(1980) investigated the profitability of a company under Logit model. The application of a financial distress models includes static univariate analysis, multivariate discriminant analysis, Logit model, Probit model and neural network, and dynamic Merton model, CUSUM and so on.

2.1 Multi-Discriminant Analysis (MDA)

Multi-Discriminant Analysis (MDA) model is a linear combination, so-called bankruptcy score of certain discriminatory variables. The bankruptcy score sorts firms into bankrupt and non-bankrupt groups according to their characteristics (Aziz* et al.*, 2006). It is stated that MDA still is the most popular technique in business failure identification and appears set a standard for comparison of bankruptcy prediction models (Altman* et al.*, 2000). It was concluded that MDA models ranked number 1 out of 16 model types and is expected to provide a reliable bankruptcy prediction method. The MDA model had an average accuracy of more than 85% in bankruptcy prediction (Aziz* et al.*, 2006). Avoiding Type I and Type II errors is also essential since misclassification can be costly to stakeholders. The error rates for MDA models showed 15% for Type I errors and 12% for Type II errors reassuring their significance as practical prediction models.

One of the advantages of the MDA is the reduction of the space dimensionality where it is transformed to its simplest form of one dimension since the purpose is to identify either if the companies are bankrupt or non-bankrupt. The object is classified using a single discriminant score namely the outcome of a discriminant function that transforms individual variable values.

Altman developed several discriminant functions; the first one called Z-score was developed in 1968 using public firms stratified by industry and size. This model has high predictive power two years prior to bankruptcy. Additionally, two adaptation of the 1968's Z-score model are presented: the Z'-score and the Z"-score. These models are summarized in Table 2.1 below including the variables present to each model.

Table 2.1: Most popular Altman's discriminant functions

Year	*Discriminant function*	*Decision Criteria*
1968	$Z = 1.2\ X_1 + 1.4\ X_2 + 3.3\ X_3 + 0.6\ X_4 + 1.0\ X_5$	Z < 1.81 bankrupted Z > 2.67 non-bankrupted Z = 1.81 to 2.67 gray area
1993	$Z' = 0.717\ X_1 + 0.847\ X_2 + 3.107\ X_3 + 0.420\ X_6 + 0.998\ X_5$	Z' < 1.23 bankrupted Z' > 2.90 non-bankrupted Z' = 1.23 to 2.90 gray area
1993	$Z'' = 6.56\ X_1 + 3.26\ X_2 + 6.72\ X_3 + 1.05\ X_6$	Z'' < 1.10 bankrupted Z'' > 2.60 non-bankrupted Z'' = 1.10 to 2.60 gray area

Where: X_1 = Working Capital/Total Assets (WC/TA)
X_2 = Retained Earnings/Total Assets (RE/TA)
X_3 = Earnings Before Interest and Taxes /Total Asset (EBIT/TA)
X_4 = Market value of Equity/ Book Value of Total Liabilities MVE/TL)
X_5 = Sales/Total Asset (S/TA)
X_6 = Net Worth (Book Value)/Total liabilities (NW/TL)

Source; Altman, 1993

The models in Table 2.1 above were built to apply to privately held firms and for non-manufacturers respectively. Both models substitute the book value of equity for the market value in X_4, making these models a little less reliable than the original. The Z"-score unlike the Z'-score, does not consider the variable X_5- Sales/total assets in order to minimize the potential industry effect of asset turnover and the effects of different types of assets financing, like lease capitalization (see Table 2.1 above).

The accuracy of the Z-score models in predicting bankruptcy has been of 72-80% reliability meaning the percentage of companies that are correctly classified in a sample of estimations. These Z-score models measure the financial health of companies and are believed to be a good diagnostic tool to predict a bankruptcy of a company. The models have gained wide acceptance for the past two decades by auditors, management consultants, courts of law and even used in database systems used for loan evaluations (Eidleman, 1995). Eidleman (1995) stated five points that many practitioners argue for the use of Z-scores approach and the disadvantages of these models.

2.1.1 Advantages of using MDA (Eidleman's five points)

(i) It is more precise and leads to clearer conclusions than contradictory ratios as well as they measure the extent of uncertainty.
(ii) It is uniform and leaves less room for inaccuracies of judgment.
(iii) It is more reliable and can be evaluated statistically. This approach is based on past experience rather than on someone's unverified opinion.
(iv) It is faster and less costly to work with than traditional tools.
(v) They can weed out the two extremes if the spectrum in an economical fashion. This allows the analyst to focus on the grey area where experience and judgment are needed to compensate for what the computer misses.

2.1.2 Disadvantages of using MDA

Eidleman also mentioned several pitfalls in using this approach; such as that models do not always give a clear result. The outcome is also never better than the numbers it is based on but people can be blinded by the model's clear accuracy if they do not fully understand how inaccurate information can be.

The Z-score models are not recommended for predicting corporate failure of financial companies. This is because the ratios that are used in the model are based on financial statements and financial firms often have off-balance sheet items that are not captured by the ratios used in the Z-score model.

The Z'-score model developed by Altman for companies in United States of America has demonstrated potential to predict bankruptcy in Argentinean companies. The researcher find it's more appropriate to use Altman's privately held company model (Z'-score) since it has worked in Argentineans companies which is believed to have the same economic condition like in Kenya. In addition, it is possible to see the different strength and performance of the companies using this model (Porporato *et al.,* 2008).

3.0 Materials and Methods

3.1 Data Collection and Methodology

The study used available data which is a set of financial ratios derived from financial statements of a sample of firms listed companies for the period from 2003 to 2007. The cut-off period was selected in order to base the analysis on as recent data as possible and capture how financially healthy these companies were in the period of economic stability and how it had developed at least five years prior to the political crisis hit in 2008.

The sample companies used in this study were selected from firms listed on the Nairobi stock Exchange (NSE) which is divided into five main sectors. The list of companies contained in the NSE Handbook (2008) was used to collect the sample that met the requirements by filtering out companies that did not fulfill the criteria that were decided. Filtering out financial and investments companies was done since the Z-score models are not applicable for financial companies because they carry off-balance sheet items as mentioned earlier. The main criteria used for sampling the firms were the firm must have been listed for the entire period of the study 2003-2007 and annual reports must be available with necessary data in the NSE Handbook (2008).

Firms that did not meet these criteria were excluded. Seven companies were excluded because they are listed after 2002 and ten were excluded because their annual reports did not provide the necessary data. The initial selection of firms was then adjusted thus;

Table 1: Sector representation

Sector	*Number of Companies listed*	*Less Companies listed after 2002*	*Less Companies information with missing data*	*Number included in the Sample*	*Percentage included in the sample*
Agriculture	4	-	-	4	100
Commercial and Services	12	4	1	7	58.3
Industrial and Allied	20	2	4	14	70.00
Alternative Investment market	8	-	3	5	62.5
Totals	44	6	8	30	

The selection resulted in a sample of 30 firms out of possible 58 firms. However, in view of some trends that were observed in alternative investment sector, one additional firm which was suspended in 2006 were selected from this category for inclusion in the sample for further testing. At least 58% of companies in each of the five sectors were included in the survey. Such a cohesive representation enables the research findings to be generalisable to companies listed on NSE since they operate with the same stock market.

The Independent variable that were applied comprised of the under listed financial ratios as per Z-score' model the chosen model for this study.

(i) X1, Working Capital/Total Assets (WC/TA)-X-
(ii) X2, Retained Earnings/Total Assets (RE/TA)
(iii) X3, Earnings Before Interest and Taxes /Total Asset (EBIT/TA)
(iv) X5, Sales/Total Asset (S/TA)
(v) X6, Net Worth (Book Value)/Total liabilities (NW/TL)

These ratios formed the coefficient applied to the Z-function, as detailed in the literature review in order to obtain a final Z-score. The Z –function used in the research is Z'-score as follows;

$Z' = 0.717\ X_1 + 0.847\ X_2 + 3.107\ X_3 + 0.420\ X_6 + 0.998\ X_5$

According to the Altman's Z'-Score analysis:

(i) When Z' is less than 1.23, the company is very likely to have financial trouble.
(ii) When Z' is between 1.23 and 2.90, the company's financial situation is fair, and there is risk of getting into financial trouble.
(iii) When Z' > 2.90, the company is financially strong.

The collected data were analyzed with the help of ratio analysis, and also through the application of Statistical Package of Social Science to run T-test and F-test. The annual reports for the year 2003-2007 were analyzed and Information derived from the financial statements was set out in a Microsoft excel spreadsheet. The spreadsheet was modeled in a way that facilitated the computation of coefficient applied to Altman Z'-score model equation. The coefficient was then multiplied by the constant and their totals added up to determine the firm's Z'-score.

Under the Altman's model, any firm that had a score over 2.90 was considered to be financially health. Firms that scored between 1.23 and 2.90 was deemed to fall within a gray area, thus they had some risk of financial troubles. Whereas, firms scored below 1.23 was considered financially distress. The data was presented in form of statements, tables and graphs.

Further analysis of the data was done using the computer based data analysis application Statistical Package for Social Science (SPSS) version 12.0. The hypotheses were tested using F-test and T-test due to the use of a sample which is not exhibiting normal distribution as the number of firms to be included was limited. The standard level of significant (5%) under this analysis was put under

consideration. The analyzed information was statistically used to come up with a conclusive result on whether to reject the hypothesis or not.

The following hypotheses were formulated for the analysis in the study;
H_O: Firms listed in NSE do not always exhibit a healthy financial position.
H_A: Firms listed in NSE always exhibit a healthy financial position.

H_O: The financial position of listed firms in NSE does not differ on the basis of sector.
H_A: The financial position of listed firms in NSE differs on the basis of sector.

H_O: The financial health of firms listed in NSE do not improves with age of listing.
H_A: The financial health of firms listed in NSE improves with age of listing.

4.0 Results and Discussion

4.1 Analysis of Financial Distress Status and Financial Performance Trend

The Z'-score results are presented for each company and all years that data was available. Each ratio that the Z'-score model is based on is analysed for all companies from the sample with perspective to how they are affected by data from the financial accounts in order to identify the main reasons behind changes in the Z'-score (the dependent variable) and to identify what is causing signals of distress or the contrary. The Z'-scores in the distressed and non-distressed zone are identified as well as those in the grey zone according to the model of the study.

The Z'-score model ($Z' = 0.717\ X_1 + 0.847\ X_2 + 3.107\ X_3 + 0.420\ X_6 + 0.998\ X_5$) state that if the score is below 1.23, the firm is distressed and if it above 2.90, the firm is non-distressed. Any Z'-score that fall in between the two points, the firm is said to be in the grey area. The T-test was used as an additional means of interpreting the results obtained from Z'-score.

Table 2: Sampled listed firms Z'-score results 2003-2007

Company Number	*Company Number*	*Company Code*	*2003 Z'-score*	*2004 Z'-Score*	*2005 Z'-Score*	*2006 Z'-Score*	*2007 Z'-Score*	*Mean Z'-score*
Agriculture	**1**	**Agri 1**	2.202	2.363	2.108	1.892	1.716	2.056
	2	**Agri 2**	0.57	1.488	0.989	1.64	1.847	1.307
	3	**Agri 3**	1.508	1.23	2.536	2.598	2.569	2.088
	4	**Agri 4**	2.39	2.832	1.63	2.259	1.764	2.175
Commercial & Services	**5**	**Com 1**	5.516	3.019	2.212	1.072	0.762	2.516
	6	**Com 2**	1.844	1.905	1.920	1.992	2.062	1.945
	7	**Com 3**	1.479	1.397	1.363	1.233	1.216	1.338
	8	**Com 4**	1.768	1.429	1.771	1.706	1.539	1.643
	9	**Com 5**	3.450	3.533	3.802	3.331	3.488	3.521
	10	**Com 6**	2.567	2.360	2.661	2.712	2.074	2.475
	11	**Com 7**	1.272	1.795	1.180	1.444	1.467	1.432
Industrial &Allied	**12**	**I&A 1**	1.796	1.524	1.334	1.091	1.757	1.5
	13	**I&A 2**	1.558	2.757	3.151	3.152	3.364	2.796
	14	**I&A 3**	3.527	3.482	3.809	3.071	2.980	3.374
	15	**I&A 4**	3.478	2.098	3.472	2.109	3.484	2.928
	16	**I&A 5**	2.205	2.049	1.384	0.809	1.674	1.624
	17	**I&A 6**	2.126	3.502	2.963	2.505	1.294	2.478
	18	**I&A 7**	0.970	0.656	1.495	1.380	1.525	1.205
	19	**I&A 8**	3.871	3.746	4.506	4.427	3.640	4.038
	20	**I&A 9**	3.830	2.961	2.643	1.979	2.528	2.788
	21	**I&A 10**	4.967	7.128	6.372	4.344	4.760	5.514
	22	**I&A 11**	1.542	2.450	2.859	2.811	2.845	2.501
	23	**I&A 12**	0.172	1.233	1.305	1.326	1.080	1.023
	24	**I&A 13**	3.775	4.299	4.424	2.880	4.085	3.893
	25	**I&A 14**	2.164	1.783	2.633	2.923	3.035	2.578
Alternative Investment	**26**	**Alt 1**	2.696	1.392	1.163	0.177	0.869	1.259
	27	**Alt 2**	1.456	1.567	1.576	1.566	1.387	1.51
	28	**Alt 2**	1.456	1.567	1.576	1.566	1.387	1.51
	29	**Alt 2**	1.456	1.567	1.576	1.566	1.387	1.51
	30	**Alt 2**	1.456	1.567	1.576	1.566	1.387	1.51

The above findings illustrate Z'-score obtained from each company in each sector and the mean score over the period of 5 years. In the model of the study, the centroid for distress firms is below 1.23 and non-distress firm is above 2.90 and any Z'-Score between these two centroids falls into the grey area. The overlap area is one where the distressed and non-distressed firm's financial

characteristics cluster together. To interpret the Z'-Scores more meaningfully, researcher generate a cutoff point to separate the Z'-Scores for both groups.

In reality, this area is where the transition period of non-distressed firms becoming failures or vice versa occurs. Furthermore, the researcher calculated and identified the cutting score at 2.065 which were interpreted using hypotheses as follows:

Table 3: Summary of the hypothesis used under different test values

Decision Criteria	*Description*	*Hypothesis*
$\mu<1.23$	Distress (D)	Ho: $\mu<1.23$ HA: $\mu\geq1.23$
$1.23\leq \mu<2.065$	Grey-Distress (GD)	Ho: $\mu<2.065$
$2.065\leq \mu\leq2.90$	Grey Non-Distress (GND)	HA: $\mu\geq 2.065$ Ho: $\mu\leq2.90$
$\mu>2.90$	Non Distress (ND)	HA: $\mu>2.90$

Where μ represent the mean of the Z'-score over a five year period calculated from the listed firms in NSE. The results were as follows;
Before making any generalizations, the model was tested for external validity. Under this test, we introduced a thirtieth firm as which consisted a firm suspended from NSE in 2007 and named as Company No. 26. It was found that the model correctly classified the entire new sample as distressed firm in their respective distress year (2006) and also two year before the actual distress.

4.1 Test of Hypothesis

The p-value approach to hypothesis testing was used and a statistical software SPSS version 12 was used. The output from the t-test, F-test and correlations were used to give a deeper insight into the study and test the hypotheses. The p-values returned by the tests were compared to the significance level (α) which was set at 0.05. The statistical decision rule was: if p-value is greater than or equal to the significance level (p-value$\geq\alpha$), the Null Hypothesis is NOT rejected. Else, if the p-value is less than the significance level (p-value$<\alpha$), the Null hypothesis is rejected.

4.2 Hypothesis Test for Financial status

To test the financial status of the listed firms in NSE, the study used the test values under the model of the study and a cutting score generated earlier by the researcher. In the model of the study, the centroid for distress firms is below 1.23 and non-distress firm is above 2.90 and any Z'-Score between these two centroids falls into the grey area with a cutoff point of 2.065. The hypotheses were therefore stated as follows:

H_O: Firms listed in NSE do not always exhibit a healthy financial position.

H_A: Firms listed in NSE always exhibit a healthy financial position.

Table 4: T-test for Agricultural Sector firms using different Test-values

Company Number	*Mean Z'-score*	*df*	*Test Value=1.23*		*Test Value=2.065*		*Test Value=2.90*		*Remarks*
			t-value	*Sig. (1-tailed)*	*t-value*	*Sig. (1-tailed)*	*t-value*	*Sig. (1-tailed)*	
1	2.056	4	7.232	0.001	(0.077)	0.529*	**	**	GD
2	1.307	4	0.330	0.379*	**	**	**	**	D
3	2.088	4	2.890	0.022	0.079	0.471*	**	**	GD
4	2.175	4	4.332	0.006	0.504	0.320*	**	**	GD

D-Distress GD-Grey Distress

* means no significance (p-value>0.05) hence we fail to reject the null hypothesis

** means that there is no need for further test since the decision has already been made

Under a test value of 1.23, only Company No. 2 returned p-value>0.05 which is 0.379 at 0.05 significance level with a t-value of 0.330 at 4 degrees of freedom. Hence, we fail to reject the null hypothesis (Ho: $\mu<1.23$) and conclude that the mean Z'-score lies below 1.23. Therefore, company No. 2 was considered to be distressed. Under a test value of 2.065, company No. 1, 3, and 4 returned a p-value>0.05 hence we fail to reject the null hypothesis (Ho: $\mu<2.065$) and conclude that the mean Z'-score lies below 2.065. Therefore, Company No. 1, 3 and 4 were considered to be in the GD zone.

The agricultural sector has major bottlenecks that affect its performance as it is known that rural areas do not have the necessary infrastructure and population growth has had an impact on the possible area for agricultural activities, agro business is not well developed in Kenya. Also the agricultural sector is at the mercy of the vagrancies of the weather. In addition to that, the unpredictability of the international market as around this time the world economy was not up beat. These factors can negatively affect the financial health of the firms in this sector.

Table 5: T-test for Commercial and Services Sector firms using different Test-values

Company Number	*Mean Z'-score*	*df*	*Test Value=1.23*		*Test Value=2.065*		*Test Value=2.90*		*Remarks*
			t-value	*Sig. (1-tailed)*	*t-value*	*Sig. (1-tailed)*	*t-value*	*Sig. (1-tailed)*	
5	2.516	4	1.510	0.103*	**	**	**	**	D
6	1.945	4	18.989	0.001	(3.199)	0.984*	**	**	GD
7	1.338	4	2.154	0.050*	**	**	**	**	D
8	1.643	4	6.064	0.002	(6.208)	0.998*	**	**	GD
9	3.521	4	29.411	0.001	18.691	0.001	7.970	0.001	ND
10	2.475	4	10.650	0.001	3.506	0.012	(3.638)	0.989*	GND
11	1.432	4	1.912	0.064*	**	**	**	**	D

D-Distress GD- Grey Distress GND-Grey Non-Distress ND- Non Distress

* means no significance (p-value>0.05) hence we fail to reject the null hypothesis
** means that there is no need for further test since the decision has already been made

Under a test value of 1.23, Company No. 5, 7 and 11 returned a p-value≥0.05 hence, we fail to reject the null hypothesis (Ho: $\mu<1.23$) and conclude that the mean Z'-scores lies below 1.23. Therefore, company No. 5, 7 and 11 are considered to be distressed. Under a test value of 2.065, company No. 6 and 8 returned a p-value>0.05 hence we fail to reject the null hypothesis (Ho: $\mu<2.065$) and conclude that the mean Z'-score lies below 2.065. Therefore, Company No. 6 and 8 were considered to be in the GD zone.

Under a test value of 2.90, company No. 10 returned a p-value>0.05 hence we fail to reject the null hypothesis (Ho: $\mu\leq2.90$) and conclude that mean Z'-score lies below 2.90, Whereas Company No. 9 returned a p-value<0.05 hence we reject the null hypothesis (Ho: $\mu\leq2.90$) and conclude that mean Z'-score lies above 2.90. Therefore, Company No. 10 was considered to be in GND zone whereas, Company No. 9 was considered to be non-distressed. Kenya at this time was at a recovery path and therefore the upturn of the economy was just beginning which can imply that it would be some time before this optimism would lead to better financial position for these firms.

Table 6: T-test for Industrial and Allied Sector firms using different Test-values

Company Number	Mean Z'-score	Df	Test Value=1.23		Test Value=2.065		Test Value=2.90		Remarks
			t-value	Sig. (1-tailed)	t-value	Sig. (1-tailed)	t-value	Sig. (1-tailed)	
12	1.500	4	2.047	0.055*	**	**	**	**	D
13	2.796	4	4.823	0.004	2.252	0.044	(0.319)	0.617*	GND
14	3.374	4	13.965	0.001	8.525	0.001	3.086	0.018	ND
15	2.928	4	5.044	0.004	2.564	0.031	0.084	0.469*	GND
16	1.624	4	1.582	0.094*	**	**	**	**	D
17	2.478	4	3.329	0.015	1.102	0.166*	**	**	GD
18	1.205	4	(0.146)	0.555*	**	**	**	**	D
19	4.038	4	15.674	0.001	11.013	0.001	6.352	0.002	ND
20	2.7882	4	5.111	0.003	2.372	0.038	-0.367	0.634*	GND
21	5.5142	4	8.112	0.001	6.531	0.001	4.95	0.004	ND
22	2.5014	4	5.056	0.004	1.735	0.079*	**	**	GD
23	1.0232	4	-0.952	0.803*	**	**	**	**	D
24	3.8926	4	9.646	0.001	6.621	0.001	3.5960	0.011	ND
25	2.5076	4	5.424	0.003	1.879	0.067*	**	**	GD

D-Distress GD-Grey Distress

* means no significance (p-value>0.05) hence we fail to reject the null hypothesis

** means that there is no need for further test since the decision has already been made

Under a test value of 1.23, Company No. 12, 16, 18 and 23 returned a p-value>0.05 hence, we fail to reject the null hypothesis (Ho: $\mu<1.23$) and conclude that the mean Z'-scores lies below 1.23. Therefore, company No. 12, 16, 18 and 23 was considered to be distressed. Under a test value of 2.065, company No. 17, 22 and 25 returned a p-value>0.05 hence we fail to reject the null hypothesis (Ho: $\mu\leq2.065$) and conclude that the mean Z'-score lies below 2.065. Therefore company No. 17, 22 and 25 were considered to be in the GD zone. Under a test value of 2.90, company No 13, 15, and 20 returned a p-value>0.05 hence we fail to reject the null hypothesis (Ho: $\mu\leq2.90$) and conclude that mean Z'-score lies below 2.90. Therefore, company No. 13, 15, and 20 were considered to be in the GND zone whereas, company No. 14, 17, 19, 21 and 24 were considered to be non-distressed. In comparison to the other sectors the number of firms not distresses was higher. This can be explained that the demand for these goods have been on the increase and provides a fairly stable return of investment as can be seen by the countries that are already industrialized.

Table 7: T-test for Alternative Investment Sector firms using different Test-values

Company Number	Mean Z'-score	df	Test Value=1.23		Test Value=2.065		Test Value=2.90		Remarks
			t-value	Sig. (1-tailed)	t-value	Sig. (1-tailed)	t-value	Sig. (1-tailed)	
26	1.259	4	0.071	0.473*	**	**	**	**	D
27	1.510	4	7.391	0.001	-14.619	1.000*	**	**	GD
28	2.257	4	7.584	0.001	1.418	0.115	-4.748	0.996*	GND
29	2.589	4	2.811	0.024	1.083	0.170	-0.644	0.723*	GND
30	2.490	4	5.920	0.002	1.996	0.058*	**	**	GD

D-Distress GD- Grey Distress GND-Grey Non-Distress ND- Non Distress

* means no significance (p-value>0.05) hence we fail to reject the null hypothesis
**means that there is no need for further test since the decision has already been made

Under a test value of 1.23, only Company No. 26 returned a p-value>0.05 hence, we fail to reject the null hypothesis (Ho: $\mu<1.23$) and conclude that the mean Z'-scores lies below 1.23. Therefore, Company No. 26 was considered to be distressed. Under a test value of 2.065, company No. 27 and 30 returned a p-value>0.05 hence we fail to reject the null hypothesis (Ho: $\mu<2.065$) and conclude that the mean Z'-score lies below 2.065. Therefore, company No. 27 and 30 were considered to be in the GD zone. Under a test value of 2.90, Company No 28, and 29 returned a p-value>0.05 hence we fail to reject the null hypothesis (Ho: $\mu\leq2.90$) and conclude that mean Z'-score lies above 2.90. Therefore, company No 28, and 29 were considered to be in the GND zone.

4.3 Hypothesis Test of Financial Status on the basis of sector

Firm that belong to the same sector are related to one another in terms of their financial status given a five year period. The financial status of each firm is estimated by the mean Z'-score calculated earlier and F-test is used in mean comparison Z'-score. Further analysis was also carried out to compare the financial status among sectors. The stated hypothesis was follows;

H_O: The financial position of listed firms in NSE does not differ on the basis of sector.

H_A: The financial position of listed firms in NSE differs on the basis of sector.

Table 8: ANOVA table of Financial Status within Agricultural Sector

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.437	3	.812	3.204	.052
Within Groups	4.056	16	.254		
Total	6.493	19			

Table 9: ANOVA table of Financial Status within Commercial Sector

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	17.949	6	2.991	5.476	.001
Within Groups	15.295	28	.546		
Total	33.243	34			

Table 10: ANOVA table of Financial Status within Industrial and Allied Sector

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	97.069	13	7.467	18.385	.000
Within Groups	22.743	56	.406		
Total	119.812	69			

Table 11: ANOVA table of Financial Status within Alternative Investment Sector

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7.191	4	1.798	3.830	.018
Within Groups	9.388	20	.469		
Total	16.579	24			

According to ANOVA test, the claim that companies within the same sector should have an equal financial status since they operate under the same economic environment is rejected. The Agricultural sector returned a p-value of 0.052 at 0.05 significant level and hence, the firms within this sector are deemed to have the same financial status simply because all firms in this sector had financial distress characteristics. In addition, with the p-value of 0.052, it can still be concluded that there is an element of differences in the firms' performance in the agricultural sector.

The other sectors had a p-value of 0.001, 0.000 and 0.018 among Commercial and Service sector, Industrial and Allied sector and Alternative Investment Segment respectively, which confirmed that the financial position of the firms in the same sector differs. This is because the financial health of a company is affected by various factors such as stock ratings, government policies, current legal affairs and incorporation of these factors other than economical environment factors is important in determination of financial soundness of business organizations. The implications of these results point to the already understood fact that management style of any firm does have an effect on the

firms' performance which can be the best explanations of the differences above between firms in the same sector.

4.4 Correlation Test between Financial Status and Age of listing

Table below shows the Pearson's correlation coefficient report between the financial status of sampled firm and age of listing. The age group categorises the companies that fall within the same range of age. Frequencies shows the number of companies within the same age group, whereas the Mean Z'-score column shows the financial status of those companies. The extreme right end reports their p-values.

The stated hypothesis was as follows:

H_O: The financial health of firms listed in NSE do not improves with age of listing.

H_A: The financial health of firms listed in NSE improves with age of listing.

Table 12: Correlation Test between Financial Health and Age of listing

Age Group	*Frequency*	*Mean Z'-score*	*Correlation*	*P-value*
5-10	1	2.501	-	-
11-15	5	1.829	0.883	0.470
16-20	2	2.758	1.000	0.500
26-30	1	2.589	-	-
31-35	3	2.503	0.855	0.347
36-40	9	2.465	0.362	0.338
41-45	2	2.332	-1.000	0.000
46-50	1	5.514	-	-
51-55	4	1.842	-0.591	0.409
56-60	2	1.888	-1.000	0.000

The claim that the financial health of firms listed in NSE improves with age of listing lacks sufficient information that can tell us if these variables are correlated or not. This is because, NSE being an emerging market, became vibrant in1996 after the largest share issue in the history of NSE, privatization of Kenya Airways, came to the market. However, the data available that can tell the relationship between financial status of listed firms and age of listing is limited in terms of age of time and therefore inadequate to make a conclusive remark on the financial status and age of listing.

5.0 Conclusion

The assessment of financial distress among firms listed in NSE was analysed in this paper using MDA approach. It was to be expected that firms listed in NSE would exhibit a strong health financial position. However, from the 30 companies analysed, only 5 companies in non-distress zone were considered in good financial health, 16 companies were in the gray area such than 10 were in grey area distress zone meaning they had a financial health as average minus and 6 were in grey area non-distress zone meaning they had a financial health as average plus. Nine companies were in distress zone meaning they were financially distressed. Therefore, the firms listed in NSE do not always exhibit a healthy financial position.

The Agricultural sector represented the most uncertain sector in terms of financial status. All companies in this category showed signs of financial distress. The sector operates under uncertain

environment and rely heavily on export hence, this include some of the factors influencing the financial status of firms in this category. The Industrial and Allied sector represented the most stable category in the context of financial health. Out of 5 companies found to have a good and strong financial status, 4 companies emerged from this sector.

It is generally assumed that firms within the same sector should not differ in terms of financial position since they operate within the same economic environment. The findings reported in the study of firms in each sector indicates that the financial status of these firms differ from one company to the other. These is because, the financial health of a company is affected by various factors such as management styles and capacity, government policies, stock ratings, current legal affairs and largely depends on how each firm is capable of coping with such factors. Therefore it is concluded that the financial position of listed firms differs on the basis of sector.

Calculating the Z-score only gives a certain number indicating a certain financial status. Although the numbers that it is based on are correct is this measurement only one helpful tool to analyze a company's health. Understanding what is behind the numbers and what is going on in the company is also essential. During years of major changes in the company's operations can cause the Z-score model to predict corporate failure and other well-known financial indicators can support or challenge the results from the Z-score analysis like the capital ratios. How the situation will develop for many of these companies is however largely depends on how the economic situation in Kenya will turn out. These companies can do their best to restructure and refinance their debt but for many of them the current debt level is too high to cope with in the long run.

5.1 Policy Implications

Several important policy implications emerge from our analysis. First, a disjoint was noted in the correlation between what is expected of the listed companies in terms of financial performance and the benefits to be accrued from CMA surveillance on them. It has also been noted that NSE has been performing poorly as evidenced when it was suspended for 15 minutes on October 2008 after its 20-share index falling below 4,000 points. This has resulted to the loss of investors' confidence and in light of the collapse of Nyaga Stockbrokers, Francis Thuo and others, the regulator is not looking good at all in the court of public opinion. This points out that the Capital Market and NSE role and responsibility needs to be strengthened. Capital Market Authority (CMA) has an array of tools it can use to ensure its subjects do not deviate from expected ethical behavior. The NSE should make financial stability an integral driver of its policy framework through adoption of financial analysis models. Further, the government should create a separate authority something akin to the Energy Regulatory Commission to oversee the CMA and NSE.

Second, we should be aware of the fact that at times the signs of a major financial distress manifest within a very short time such that the predictive ability of financial ratios become temporarily redundant. This situation is common during an unexpected recession. Nonetheless, financial ratios would give vital information to different stakeholders under normal operating and financing business atmosphere. It is therefore recommended that the practical applicability of bankruptcy prediction models should be checked after some period of time as the economy changes.

Thirdly the industrial and the allied sector firms exhibited better financial health in comparison to the firms from the other sectors. This implies that there is need for a concerted effort for investors to focus on these groups of firms. They are capable of offering more stable dividends and equally more the Kenyan economy towards industrialization.

Fourthly it has been noted that the agricultural sector seems to be having its own woes as far as its financial health is concerned. This brings into sharp focus the need for some prioritization of this

sector and the need to address the issues in this sector. For industrialization agriculture cannot be left behind as it is the sector that provides the necessary resources such as food ensuring a healthy population and earnings from export which are critical if ever industrialization is to be realized in the shortest time possible.

Lastly for the agricultural sector there is need to focus on value addition to the produce of this sector as this might ensure a better financial health for these firms as exhibited by the industrial and allied sector that had the better financial health comparatively. Value addition may involve processing thereby bringing in manufacturing and the benefits that go with it.

6.0 Further Research

The study tried to strengthen the position of existing work in bankruptcy prediction, particularly based on the Altman models. Presented below are few suggestions researchers might extend this research in several directions.

(i) Researchers should investigate development of bankruptcy prediction models using different statistical methodology other than multi-discriminant analysis, such as artificial neural networks (ANNs), logit or probit analysis, to compare and select the most efficient model.

(ii) Another research area that could be extended is to test bankruptcy prediction models to the non-listed, relatively smaller turnover sized firms where the incidence of business failure is greater than larger corporations.

(iii) Since the data in the study was limited to a certain period of time, researchers should also extend the research by investigating the relationship between the age of listing and financial health of sampled firms.

(iv) Another research could be done to come up with a model suitable to investigate the financial distress among financial institutions since the Altman's Z-score models are not recommended for these institutions.

References

Aiyabel, J. (2000). Financial Distress: Theory, Measurement and Consequence, *The East Africa Journal of Humanities and Science*. Vol. **1**-2002.

Altman, E. I. (1968). Financial Ratios, Discriminant Analysis and the Prediction of Corporate Bankruptcy, *Journal of Finance*, **23.**

Altman, E. I., (1983). Corporate Financial Distress: A Complete Guide to Predicting, Avoiding and Dealing with Bankruptcy, Toronto: Wiley and Sons.

Altman, E. I. (1993). Corporate Financial Distress and Bankruptcy. A complete guide to Predicting and Avoiding Distress and Profiting from Bankruptcy. Second Edition. USA, John Rileyand Sons Inc.

Altman, E. (2000). *Predicting Financial Distress of Companies: Revisiting the Z-Score and Zeta ® Models*. (Supplement: Altman, E., 1968: Altman, E., Halderman, R., and Narayanan, P., 1977). Stern School of Business, New York University.

Arnold, G. (2002). Corporate Financial Management. 2nd edition. Harlow: Pearson Education Limited. "Model distress and recovery predictions, *Financial Analysis Journal.*

Aziz, M. Adnan and Dar, Humayon A. (2006). Predicting Corporate Bankruptcy: where we stand? *Corporate Governance*, Vol. **6** (1), pp. 18-33.

Beaver, W. (1967). Financial Ratios as predictors of Failure. *Journal of Accounting Research (supplement),* 4.

Bruno, A. V. and Leidecker, J. K. (2001). Causes of new venture failure: 1960 vs. 1980. *Business Horizon*. November-December 1988.

Bryman, A. and Bell E. (2007). Business Research Methods. 2nd edn. Oxford University Press.

Charitou. A., Neophytou, E. and Charalambous, C. (2004). Predicting Corporate Failure: Empirical Evidence for the UK., *European Accounting Review*, **13** (3).

Deakin, E. (1972). A Discriminant Analysis of Predictors of Business Failure. *Journal of Accounting Research,* vol. 10(1).

Eidleman, Gregory J. (1995-02-01). Z-Scores - A Guide to Failure Prediction. *The CPA Journal Online*, 07328435, Feb 95, Vol. **65**(2) Business Source Complete.

Elloumi F. and Gueyie J. (2001). Financial distress and corporate governance: an empirical analysis. Corporate Governance: *International Journal of Business in Society*, **1** (1), pp 15- 23.

Escott, P., Glormann, F., and Kocagil, F. K. (2001). Modeling Methodology**.** McGraw-Hill International Editios. Singapore.

Fisher, R. A., (1936). The Use of Multiple Measurements in Taxonomic Problems, *Annals of Eugenics,* No. 7.

Grice, J. S. and Dugan, M. T. (2001). The Limitation of Bankruptcy Prediction Models: Some Cautions for the Researchers. *Review of Quantitative Finance and Accounting,* **17**(2).

Halim, A., Alumnad, H. and Md.Rus, R. (2008). Predicting Corporate Failure of Malaysia's Listed Companies: Comparing Multiple Disscriminant Analysis, Logisitic Regression and Hazard model. *International Research Journal of Finance and Economics* ISSN 140-2887 issue 15-2008. Euro Journals publishing Inc.

Hamada, R. S. (1972). The effect of the firm's capital structure on the systematic risk of common stock, *Journal of Finance.*

Haniffa, R. M. and Cooke, T. E. (2002). Culture, Corporate Governance and Disclosure in Malaysian Corporations. Abacus, vol. **38**(3).

Harlan and Marjorie. (2002). Predicting corporate financial distress: Reflections on choice – based sample bias*. Journal of Economic andFinance*, **26**(2), pp 184.

Jones, S. and Hensher (2004). Predicting Firms Financial Distress: A Mixed Logit Model, *The Accounting Review,* **79**(4).

Kilman, R. H. and Coven, T. J. (1988). Corporate Transformation. Revitalizing Organizations for a Competitive World. Jossey-Bass, St. Francisco, USA.

Kothari, C. R. (2004). Research Methodology. Methods and Techniques. 2nd Edition. New age International (P) Limited, publisher.

Libby, R. (1985). Accounting ratios and the prediction of failure: some behavioral evidence, *Journal of Accounting Research,* **13**.

Lennox, C. (1999). Identifying Failing Companies: A Re-evaluation of the Logit, Probit and MDA Approaches, *Journal of Economics and Business*, **51** (4).

Mugenda, O. M. and Mugenda, A. G. (2003). Research Methods. Quantitative and Qualitative Approaches. African Centre for Technology Studies (ACTS).

Mohamed, S., Li, A. J. and Sanda A. U. (2001). Predicting corporate failure in Malaysia: An application of the Logit Model to financial ratio analysis. *Asian Academic of Management Journal*, **6**(1).

Nam, J. and Jinn, T. (2000). Bankruptcy prediction: Evidence from Korean companies during the IMF crisis. *Journal of International Financial Management and Accounting*, **11**(3).

Ngugi, R., Amanja, D., Maana, (2009). Capital market, financial deepening and economic growth in Kenya.

Ohlson, J. (1980). "Financial Ratios and the Probabilistic Prediction of Bankruptcy", *Journal of Accounting Research,* vol. **18**.

Parker, S., Peters, G. F. and Turetsky, H. F. (2002). "Corporate Governance and Corporate Failure: A survival Analysis", Corporate Governance: *International Journal of Business in Society,* Vol. **2**(2).

Pereiro, L. (2006). The practice of Investment Valuation in Emerging Markets: Evidence from Argentina, *Journal of Multinational Financial Management,***16**.

Polesie, T. (1991). Continuity and Change: Corporate Identity in a Scandinavian Perspective. BAS, Gothenburg School of Economics.

Sandin, A. R. and Porporato, M. (2008). “Corporate Bankruptcy Prediction Models Applied to Emerging Economies: Evidence From Argentina in year 1991-1998”, *International Research Journal of Finance and Economics* ISSN 140-2887 issue 15-2008. *EuroJournals publishing Inc.*

Stickney, C. P. (1996). Financial Reporting and Statement Analysis. A Strategic Perspective. 3rd Edition. Ft. Worth, TX: The Dryden Press.

Wruck, K. (1990). "Financial Distress: Reorganization and Organization Efficiency", *Journal of Financial Economics* Zmijewski, E. (1984). Methodological Issues Related to the Estimation of Financial Distress Prediction Models. Journal of Accounting Research, vol. **20.**

Zmijewski, E. (1984). Methodological Issues Related to the Estimation of Financial Distress Prediction Models. Mohamed , S., Li, A.J. and Sanda A.U. (2001). Predicting corporate failure in Malaysia: An application of the Logit Model to financial ratio analysis. *Asian Academic of Management Journal*, **6**(1).

Zulkarnain, M. S., Mohamad Ali, A. H., Annuar, M. N. and Zainal A. M. (2001). Forecasting corporate failure in Malaysian industrial sector firms, *Asian Academy of management Journal*, **6**(1).

ADOPTION AND USE OF INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) BY SMALL ENTERPRISES IN THIKA TOWN, KENYA

S. O. Mokaya[1] and E. W. Njuguna[2]
[1]Jomo Kenyatta University of Agriculture and Technology
[2]Mabati Rolling Mills
E-mail: skomokaya@yahoo.com

Abstract
Information and communications technology (ICT) has assumed a critical role in facilitating socio-economic development in many countries. The contribution of ICT to enterprise development has been recognized and many countries including Kenya have made deliberate efforts in integrating ICT into small enterprise (SE) development agenda. However, the adoption and use of ICT by small enterprises has been below expectations. The study sought to determine factors affecting the adoption and use of ICT by (SEs) Kenya. The study was conducted through a survey questionnaire covering a stratified sample of 78 respondents drawn from 390 SEs in Thika. Both qualitative and quantitative methods were used to analyze data. Chi-square tests were conducted to establish the relationship between variables. Results indicated that most SEs use basic communication tools such as mobile (75%), internet (34.6%). Adoption and use of ICT tools has not been well embraced by SEs. Most SEs are characterized by weak financial capacity and hand-to-mouth financial existence. The chi-square value was 7.890 with 0.049 significance level, indicating a statistically significant relationship between financial capacity and ICT adoption and use. SE operators perceive the cost of ICT to be very high, with a negative effect on adoption and use. Communication infrastructure was also found to have a significant effect on adoption and use, having a chi-square value was 21.65 with a 0.001 significance level. The level of knowledge and education also has significant effect on adoption and use having a chi-square test value of 16.063 and a 0.013 significance level. The study concludes that adoption and use of ICT has not been well embraced by SEs. All the variables under study have a statistically significant effect on ICT adoption and use. To help improve ICT adoption and use by SEs in Kenya, the Government should develop an appropriate programme to encourage ICT adoption and use by SEs, eliminate all taxes on ICT, establish a special fund to support ICT adoption; support training programmes to develop the capacity of SEs to embrace ICT; invest in appropriate communication infrastructure for SEs, and there should be deliberate efforts by Government to encourage SEs to invest in basic ICT tools to help improve their business and make them more competitive.

Key words: Information and communication technology, small enterprise, adoption and use, infrastructure, financial capacity, cost, knowledge level

1.0 Introduction

Information and communications technologies (ICT) have assumed a central position in the development agenda of most countries due to their critical role in facilitating socio-economic development (Frempong, 2004). The contribution of ICT to enterprise development has been recognized and many countries including Kenya have made great efforts in integrating ICT into the enterprise development agenda. Kenya has developed and enacted an ICT policy, with the enterprise sector being one of the targeted areas of intervention.

The role of SEs to employment and wealth creation as well as poverty reduction is well pronounced. The small enterprise sector is currently one of the fastest growing, providing much of the needed employment and playing a critical role in poverty reduction programmes. Small businesses also serve as seedbeds for entrepreneurs, contribute to more balanced development and facilitate the process of adjustment in large enterprises, emerging as competent suppliers of products and services previously not available in the market place.

At the sectoral level, small enterprises account for 75% of all new jobs created and 61% of all wage employment in Kenya (ICEG, 1998). Further, the sector contributes 15% of GDP and constitutes 98% of all businesses in the country. However, they operate in an environment characterized by fragmented and incomplete information where awareness of markets, technology, policy, regulations and finance is limited (Kabiru, 1996). This affects entrepreneurial activity since the absence of information impinges on the scope for discovery of profitable opportunities.

In the context of globalization, it is doubtful that the SEs will take advantage of the emerging opportunities in the local and export markets in the presence of imperfect markets and information. Even when entrepreneurs know where to obtain information, the potential of incurring social or economic costs act as deterrents. Information is the basic requirement for enterprise creation, growth and survival; and ICT is capable of easing information gaps in the business sector. ICT enhances SE efficiency, reduces costs, and broadens market reach, locally and globally; resulting in job creation, revenue generation and overall country competitiveness.

Whereas ICT is a key ingredient to the development, growth and survival of vibrant enterprises, its adoption and use by SEs in Kenya is below expectations. A number of factors hinder the use of ICT by SEs and therefore, keep them away from enjoying the benefits of ICT; weak knowledge base, resources constraints and affordability, accessibility and poor infrastructure. The SE sector, in virtually all countries, plays a key role in national economic development strategies by facilitating flow of information, capital, ideas, people and products. Whereas ICT is not a panacea for all development problems, it offers enormous opportunities to reduce social and economic inequalities, particularly those related to income generation, poverty reduction, education, health, environment and gender equity, and thus help achieve broader development goals. ICT will increasingly empower SEs to participate in the knowledge economy by facilitating connectivity; helping to create and deliver products and services on a global scale, and providing access to new markets and new sources of competitive advantage to boost income growth.

1.1 Statement of the Problem

The benefits of ICT adoption and use by SEs range from opportunity and market access to operational efficiencies and making enterprises more competitive and successful. Failure to adopt information and communications technologies has led to high cost of production and hence low profits. Business inter-linkages and networking is greatly hampered to the extent that entrepreneurs do not know about new products in the supply chain or even consumer demands, resulting in market mismatch between demand and supply. In effect, businesses continued to be operate in markets that are no longer profitable due to competitive pricing and hence business collapse.

In the Kenyan situation where SEs are the dominant economic operatives, ICT offers great potential for growth, profitability and competitiveness. As much as the Government is committed to facilitate widespread use of ICT to support the growth of micro and small enterprises, and boost e-business, knowledge on the status of ICT adoption and use and the barriers to adoption are critical starting points. However, ICT adoption and use by SEs in Kenya has been below expectations and is of concern to policy makers, academia and development partners.

1.2 Purpose

The purpose of the study was to determine the factors that affect ICT adoption and use by small enterprises in Kenya, in an effort to making appropriate recommendations to improve access and use. Specifically the study sought to determine the effect of financial capacity on ICT adoption by small enterprises in Kenya; assess the influence of cost on adoption of ICT by small enterprises in Kenya; determine the effect of the infrastructure on ICT access and use by small enterprises in Kenya, and establish how knowledge level affects the adoption of ICT by small enterprises in Kenya

1.3 Methodology

The study was descriptive in nature, conducted through a survey questionnaire, covering a population of 390 small enterprise operators in Thika Town. A stratified sample of 78 SMEs was used to collect data. There was preliminary analysis involving production of frequency distributions for all the variables and cross-tabulation for categorical data. Qualitative data, consisting of words, was analyzed logically and systematically by organizing data into categories; shaping it into information; interpreting and summarizing the information. Quantitative data was analyzed using measures of central tendency. Chi-square tests were conducted to determine the relationship between variables and their effects on adoption. The objective of this analysis as supported by Kothari (2004) was to make a prediction about the dependent variable (ICT adoption) based on its covariance with all the independent variables (the factors).

3.0 Results and Analysis

According to the study findings (Table 1), most proprietors of small enterprises have attained college level education (38.5%) and are therefore expected to be aware of ICT tools. Most business enterprises in Thika town use basic communication tools such as mobile (75%), internet (34.6%) and simple computer based programmes.

Table 1: ICT tools used in the enterprises

Technology/ Gadget	Response			
	No		Yes	
	F	%	F	%
Mobile	13	25.0	39	75.0
Internet	34	65.4	18	34.6
Computer	30	57.7	22	42.3
Radio	50	96.2	02	03.8
Television	50	96.2	02	03.8
Calculator	50	96.2	02	03.8

Source: Survey data, 2010

The access and use of ICT tools has not been well impressed by majority of the enterprises in Thika town. 26.9% of the respondents felt that their access to and use of ICT was very high. Approximately 15% of the respondents also felt that their access and use was high. However, more than 50% of the respondents reported average to very low access and use of ICT tools.

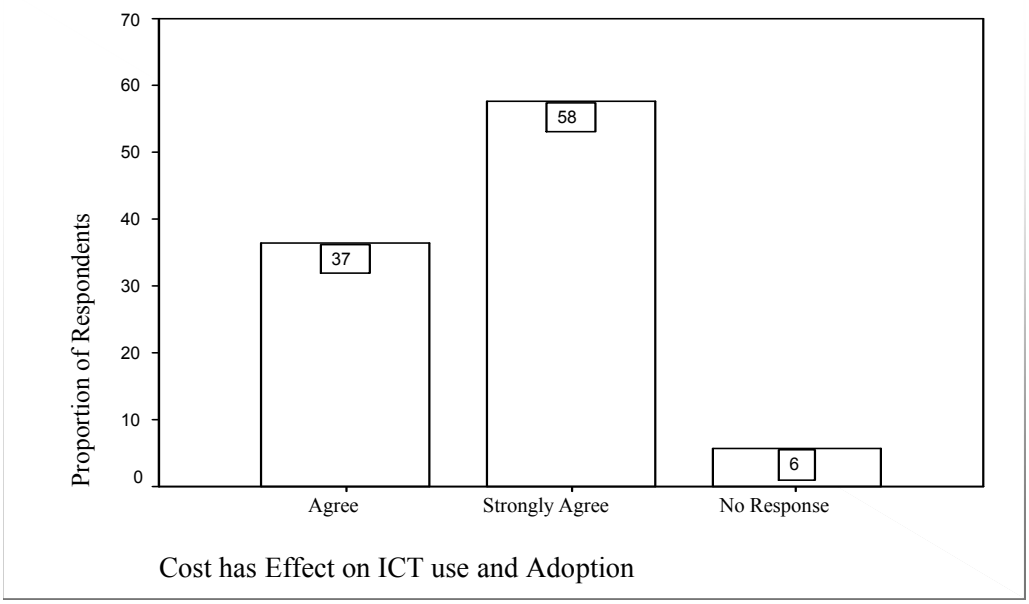
Most businesses entrepreneurs feel like they a weak financial capacity to invest in ICT structures and tools for better management of their business. They felt that their financial capacity is limited to the basic requirements of a business. As shown in Table 2, 56% of the respondents strongly disagreed with the statement "I have set aside a special ICT fund for my business". Consequently, 58% of the respondents either agreed or strongly agreed to the statement "my hand to mouth financial existence" cannot allow me to use ICT tools. This means that most businesses in Thika Town do not consider investment in ICT as a priority. This is partly because their financing options are limited hence they would rather utilize the available funds to stock or expand their business first. The chi-square value of 7.890 has a significance level of 0.049 which is less than the acceptable alpha of 0.05. This establishes a statistically significant relationship between financial capacity and access and use of ICT. This means that financial capacity of the business proprietors affects ICT adoption by small enterprises in Thika.

Table 2: Effect of financial capacity on ICT Adoption

Item	Response							
	SD		D		A		SA	
	F	%	F	%	F	%	F	%
1. I have enough money in my business to invest in ICT	19	36.5	14	26.9	14	26.9	05	09.6
2. Hand to mouth financial existence cannot allow me to use ICT	11	21.2	11	21.2	17	32.7	13	25.0
3. I have set aside a special ICT fund for my business	29	55.8	03	05.8	15	28.8	05	09.6
4. Financial capacity of an enterprise has an effect on ICT Adoption	02	03.8	03	05.8	13	25.0	34	65.4

Source: Survey Data, 2010

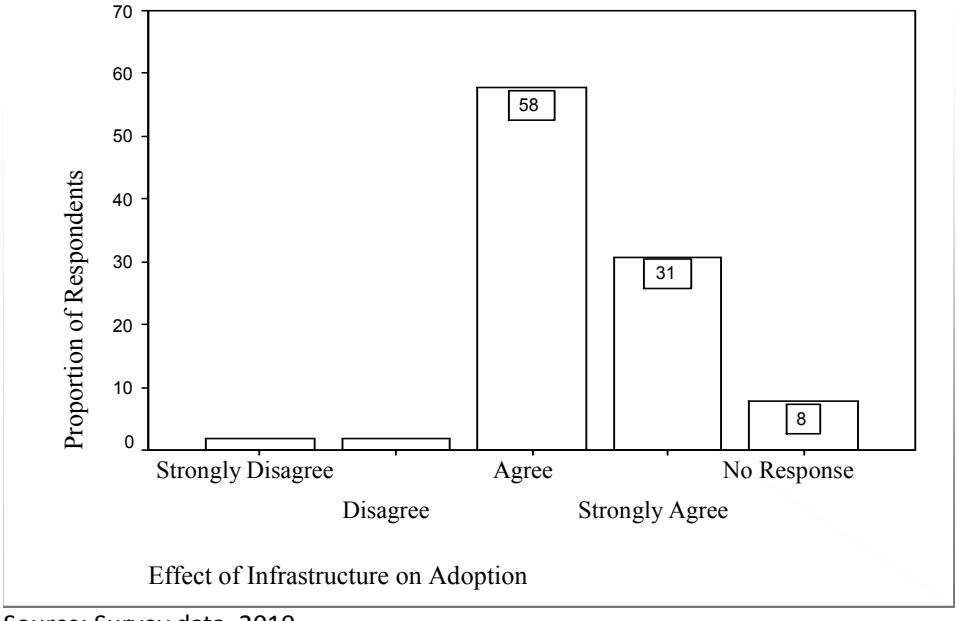
Most business owners believe that the cost of ICT tools is high and it discourages investment in ICT structures and tools hence the poor adoption levels. According to the study findings (Figure 1), majority of the respondents (58%) strongly agree that cost of ICT has an effect on ICT use and adoption in small scale enterprises in Thika town. None of the respondents disagreed with the statement. This means that cost has had a negative impact on the adoption and use of ICT tools in Thika. The feeling is that Taxation on ICT is high and that prices of some ICT tools has been inflated making it unaffordable.



Source: Survey data, 2010

Figure 29: Effect of cost on ICT use and adoption

Although communication infrastructure is a pre-requisite to the use of ICT, most business persons felt that the infrastructure is not well developed to boost ICT adoption. The results in Figure 2 show that almost all respondents felt that communication infrastructure affects the adoption of ICT by small scale enterprises in Thika town. Considering that infrastructure is one of the pre-requisite of ICT adoption, its poor state or lack of it would definitely affect access and use of ICT tools. 46% of respondents agree that internet modems on offer are too expensive. Approximately 30% belief that internet connection requires fixed telephone lines that are expensive to install. On the other hand 60% of respondents feel that ICT infrastructure in Thika is not adequate.



Source: Survey data, 2010

Figure 2: Influence of Infrastructure on access and use of ICT

Cross tabulation was performed with chi-square statistics to establish if there is a relationship between communication infrastructure and access and use of ICT. The chi-square value of 21.65 has a significance level of 0.001 which is far less than the acceptable alpha of 0.05. This establishes a statistically significant relationship between communication infrastructure and access and use of ICT. The level of knowledge on ICT systems as well as education level of the business proprietor was found to have a significant relationship with ICT adoption. More knowledgeable and learned proprietors are more likely to adopt ICT than less knowledgeable and learned proprietors.

Majority of the respondents agreed with the assertion that knowledge level affects ICT adoption and use (Table 3). Only 4% of the respondent disagreed. Further, 46% of respondents do not see the importance of ICT in their business. Approximately 50% of the respondents also do not have prior knowledge on ICT opportunities. However, majority of the respondents agreed with the assertion that they do not understand the importance of ICT. They do not see ICT as necessary in their business.

Table 3: How knowledge level affects adoption

Statement	Response							
	SD		D		A		SA	
	F	%	F	%	F	%	F	%
1. Do not see the importance of using ICT in my business	15	28.8	11	21.2	12	23.1	12	23.1
2. I have no prior knowledge on ICT Opportunities	15	28.8	08	15.4	15	28.8	12	23.1
3. I do not understand the importance of ICT use in my Business	21	40.4	09	17.3	09	17.3	11	21.2

Source: Survey data, 2010

Cross tabulation with chi-square test was performed to determine if access to and use of ICT has a relationship with level of education of the proprietors of enterprises. The chi-square test value was 16.063 with a significance level of 0.013 (Table 4). The significance level is far less than the acceptable alpha of 0.05 thereby establishing a statistically significant relationship between education level of enterprise proprietor and adoption of ICT.

Table 4: Relationship between level of education and level of ICT adoption

Level of education	Access and use of technology						Total	
	High		Average		Low			
Primary	0	0.0	1	1.9	4	7.7	5	9.6
Secondary	4	7.7	7	13.5	5	9.6	16	30.8
College	9	17.3	5	9.6	6	11.5	20	38.5
University	9	17.3	1	1.9	1	1.9	11	21.2
Total	22	42.3	14	26.9	16	30.8	52	100.0

Chi-square test: Value = 16.063, df = 6, Significance = 0.013
Source: Survey data, 2010

Proprietors with primary level of education reported low ICT adoption while those who had at least college level of education reported high access and use of ICT tools. This implies that level of education significantly affects the access and use of ICT among business within Thika Town.

4.0 Conclusions

The access and use of ICT tools has not been well impressed by majority of the enterprises in Thika town, thereby indicating a low level of adoption and use. The entrepreneurs have a weak financial capacity to invest in ICT structures and tools for better management of their business. Their financial capacity is limited to the basic requirements of a business. There is a statistically significant relationship between financial capacity and access and use of ICT, implying that financial capacity of the business proprietors affect ICT adoption by small enterprises in Thika.

Most business owners believe that the cost of ICT tools is high, which discourages investment in ICT structures and tools hence the poor adoption levels. This means that cost has had a negative impact on the adoption and use of ICT tools in Thika. There is a relationship between communication infrastructure and access and use of ICT as supported by a chi-square value of 21.65 with a significance level of 0.001 which is far less than the acceptable alpha of 0.05, indicating a statistically significant relationship between communication infrastructure and access and use of ICT. Some technologies would require landline or LAN systems which are actually designed for larger enterprises.

The level of understanding on various ICT tools hinders adoption. Although most of them are aware of their existence they do not think that such technologies are necessary for their SMEs. Small enterprises which have not embraced ICT attribute the status to their inability to finance ICT infrastructure. The SMEs are operating on a lean capital base that would not allow them allocate some fund to ICT development some actually, operate from hand to mouth. Lack of investment in ICT is attributed to their subsistence financial capacity.

Therefore, the level of education significantly affects the access and use of ICT among business within Thika Town. Proprietors with primary level of education reported low ICT adoption while those who had at least college level of education reported high access and use of ICT tools.

5.0 Recommendations

The Government should make ICT more affordable to SEs by lowering the tax and regulating their prices so as to curtail dealers inflating prices. The Government through the ministries of Trade and, Information and Communication should initiate and support training programmes to develop the capacity of small and medium entrepreneurs in ICT tools.

The Government should source for and invest in communication infrastructure targeting small and medium enterprises. The Government should make deliberate programmes to create awareness on the utility of ICT use in SMEs. Further, SEs should start investing in basic ICT tools to help improve their business management practices in line with global trends. This will make them more competitive and help access global markets.

References

Brown, D., Lockett, N. and Schubert, P. (2005). Preface to the focus theme section 'SMEs and E-Business', *Electronic Markets*, Vol. **15**(2).

Caldeira, M .M. and Ward, J. M. (2002). "Understanding the successful adoption and us of IS/IT in SMEs: an explanation from Portuguese manufacturing industries" *Information Systems Journal*, Vol. **12.**

Chadwik, M. and Rumfitt, A. (2002). Intervention versus market forces in the enablement of London's SMEs: the role of business link for London. Shared Intelligence and Business Link for London.

Harindranath, G. Dyerson, R. and Barnes, D. (2008). "ICT Adoption and Use in UK SMEs: A Failure of Initiatives? *The Electronic Journal Information Systems Evaluation,* **11(**2) (available online at www.ejise.com).

Keen, P. and MacDonaold, M. (2000). The eProcess Edge, Berkley, Osborne/McGraw Hill, California Kotelnikov, V. (2007). Small and Medium Enterprises and ICT. A publication of the United Nations Development Programme.

Levy, M., Powell, P. and Worrall, L. (2005). "Strategic intent and e-business in SMEs: Enablers and inhibitors", *Information Resources Management Journal*, Vol. **18**(4).

Levy, M., Powell, P. and Yetton, P. (2001), "SMEs: Aligning IS and the strategic context", *Journal of Information Technology*, Vo. **16.**

METI (2001). *White Paper on Small and Medium Enterprises in Japan*, SME Agency of Japan (available at http://www.chusho.meti.go.jp/hakusyo/h13/download/2001eibunzennbun.pdf).

Moodley, S. (2002). "E-Business in the South African Apparel Sector: a Utopian Vision of Efficiency?" The Developing Economics OECD (2002a). "The Impacts of Electronic Commerce on Business: Summary", STI/ICCP/IE(2002)5/FINAL, OECD, Paris OECD (2004). ICT, E-BUSINESS AND SMEs, OECD, Paris.

Pool, P. W., Parnell, J. A., Spillan, J. E., Carraher, S. and Lester, D. L. (2006). "Are SMEs meeting the challenge of integrating e-commerce into their businesses? A review of the development, challenges and opportunities", *International Journal of Information Technology and Management*, Vol. **5**,(2/3).

Rae, A. (2006). Abandoned Heroes – ICT Adoption and Use in SMEs. West Focus ICT Project.

Sakai, K. (2002). "Global Industrial Restructuring: Implications for Small Firms", STI Working Papers 2002/4, OECD, Paris (available at http://www.oecd.org/sti/working-papers).

Tetteh, E . and Burn, J. (2001). Global Strategies for SME-Business: Applying the small framework. *Logistics Information Management*, Vol. **14.**

EFFECTIVENESS OF QUALITY ASSURANCE AT KENYAN UNIVERSITIES: A CASE OF JOMO KENYATTA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY

J. Obwogi, and R. O. Otieno
Jomo Kenyatta University of Agriculture and Technology, Nairobi Kenya
Email:josephobwogi@yahoo.com

Abstract
The purpose of this study was to assess the effectiveness of quality assurance in Kenyan Universities with a specific focus on Jomo Kenyatta University of Agriculture and Technology. The research sought to establish the effect of Government of Kenya regulations relationship on university quality assurance; the effectiveness of quality assurance practices on teaching and learning; and the challenges facing quality assurance initiatives. A descriptive study in form of a survey was undertaken on a population of 10,739 students and 1,000 employees, from both gender. Stratified random sampling was used to select respondents consisting of both staff and students. The findings of the study revealed that the university has a policy for quality assurance and also provides for external review of programmes, that quality assurance at the university is effective and quality assurance mechanisms are in place that the university has clear mechanisms for teaching and learning and rules and regulations are consistently applied during student evaluation and the examination processing. The teaching staff is able to handle assignments and continuous assessment tests as guided by the course objectives; meet the course requirements, and regularly attend class. However, institutional facilities and services such as library, internet connectivity, academic trips, need to be addressed further. The study recommends that the university takes all actions to ensure that quality assurance standards and procedures are adhered to; and that delivered products or services meet performance requirements and standards.

Key words: Effectiveness, quality assurance, academic quality

1.0 Introduction

The word "effectiveness" seems to mislead people into thinking that it implies the effectiveness of the system in meeting the specified requirements and the prescribed quality objectives, whereas in fact it refers to the effectiveness of the system in meeting and complying with the specified requirement of the business system (BS) standards (Evans & Lindsay, 1996).

Quality assurance in higher education has been important for decades. Quality helps in improving professional standards by comparing them with international educational qualifications. Several attempts have been made to develop quality certifications in this field such as the method ISO 9000 and others that derive from the manufacturing industry (Dolinsek and Rupnik, 1999).

Universities are highly regarded as key vehicles for the pursuit of all of the national and continental development aspirations intrinsic to political, economic, and intellectual decolonization. In terms of the 'core business', this means the production of both knowledge and people equipped with the intellectual capacities needed to pursue national and regional advancement (Ajayi, 1996).

The Government of Kenya introduced free primary education immediately after the December 2002 elections. The elimination of school fees, an obstacle to education for impoverished families in many African countries, has, at a stroke, put the country "on track" to reach the high enrolment and low parity objectives, at least in primary education. In 2004 the UN Children's Fund (UNICEF) estimated that the country's total primary school enrolment was nearly 7.4 million, compared to less than 6 million in the Millennium year of 2000. Equally impressive has been Kenya's success in reducing dropout rates from 4.9 % in 1999 to just 2 per cent in 2003, despite the difficulties that followed the introduction of free primary education (MOEST, 2006).

Kenya has seven public Universities and over 17 private universities with an enrolment of about 100,000 students. Besides, more than 60,000 students are enrolled in middle-level colleges that cater for a variety of post-secondary career courses leading to the award of certificates, diplomas, and higher diplomas& In fact, by 1990, Kenya had just about 160 middle-level colleges; but by 2000, it was estimated that the country had more than 250 of them(MOEST, 2006).

Jomo Kenyatta University of Agriculture and Technology (JKUAT) was established through an Act of parliament as a middle level college of Agriculture and Technology and started operations in April 1981. It developed into a constituent college of Kenyatta University in July 1988 and was finally established as a full fledged university through the Jomo Kenyatta University of Agriculture and Technology Act of parliament in 1994.

Currently, JKUAT has 11,739 students and 1,000 staff members falling into two categories of faculty and non teaching/administrative staff. The university has grown rapidly into 4 campuses and 4 university colleges. In this growth, Concerns about quality become legitimate.

2.0 Statement of the Problem

Institutions of higher learning exist to fulfill certain mandates including; training, research, innovation, technology transfer, maximizing the stakeholders' interest, social responsibility, ethics, and market leadership. The achievement of this mandate has however not been easy due to increased demand for university education in Kenya while the resources are still minimal. The government, as the chief financier of university education in Kenya, has reduced its contribution to university education to around twenty percent of budgetary allocation for universal education while at the same time directing the same institutions to admit more students. The imbalance of resources against admission has led to questions on the quality of both the programmes and the graduates.

The government of Kenya, through the Commission for Higher Education has established systems of external quality assurance (QA) to ensure that institutions of higher education meet the expected national and international competitiveness. The application of these policies is however not standard across the universities. An issue that has received little attention is whether broadening the remit of national quality regimes is counterproductive and working against improvements in teaching and learning (Bradley, 2005). There is therefore an urgent need to investigate whether the procedures for evaluating teaching and learning, government requirements with regard to quality, and other sectoral aims are effective.

2.1 Objectives

The objective of this study was to examine the effectiveness of quality assurance practices at institutions of higher learning with specifics on establishing the effect of the Government regulations on JKUAT quality assurance, examining the effectiveness of JKUAT quality assurance practice on teaching and learning and identifying the challenges facing quality assurance initiatives at JKUAT.

2.2 Research Design

A descriptive study in form of a survey describing a phenomenon associated with subject population or estimating proportions of the populations with certain characteristics was undertaken. In the research, the dependent variable was the effectiveness of quality assurance while the independent variables included the quality assurance systems, the quality assurance indicators and the challenges of quality assurance.

The target population comprised of staff and students of Jomo Kenyatta University of Agriculture and Technology, consisting of 10,739 students and 1,000 employees, from both gender. Probability sampling technique was used in this study using stratified random sampling. The criteria used for stratification was the cadre (students/staff) and geographical distribution, giving a total of five strata. The total sample of the study included 8 members of staff and 42 students distributed by location, based on the optimal allocation with fixed sample size (Neyman allocation).

2.3 Data Collection

Questionnaires were used to collect data, developed directly from the research objectives and research questions. A pilot run was made at the main campus before rolling out at all the campuses. In some instances, the researcher guided the administration of the questionnaire by physically being present during the exercise. A total of 50 questionnaires consisting of 84 % students and 16 % staff were responded to from the main campus and other JKUAT campuses.

2.4 Data Analysis

The data collected was analyzed using both descriptive and inferential statistics. For qualitative data, summary of all responses was made and common items identified. The pearson correlation coefficient, means, maximum, minimum, standard deviations and percentages were computed. The items in the questionnaire were grouped into three categories representing the three research objectives. Tables, figures, frequencies, charts and graphs representing the percentage and average quality practices were run.

3.0 The effect of the Government Regulations on quality assurance

In establishing the effect of the Government regulations on quality assurance relationship, a number of items relating were responded to. The existence of a quality assurance policy that defines the roles of all stakeholders towards quality assurance practices was given the highest rating (mean of 3.78). As also pointed out by El-Khawas (2001), the accommodation between government and higher education has been to negotiate the establishment of an external QA regime premised upon

partnership between government and higher education through direct participation of educational experts in decisions touching on education. The Commission for Higher Education has provided guidelines for curriculum development across all universities and unless and until any new programmes have satisfactorily met all these requirements, they cannot be rolled out.

The impact of the quality assurance policy on university programmes was well versed with the respondents, with 58% of the respondents agreeing that the quality assurance policy is compliant to the CHE and government of Kenya regulations while 52% of the respondents agree that the quality assurance policy addresses all issues relating to quality of university programmes**.**

Majority of the respondents positively identify the relationship between government and higher education on quality and quality related issues and recognize the Commission of Higher Education as a key government vehicle for assuring quality with over 54% of the respondents in agreement. This is similar to earlier recognition by Bradley's (2005) that great increases in participation, greater diversity of entrants, decreased or stable per capita funding and institutional reshaping have led to many questions that address the competitiveness, effectiveness and efficiency of universities. There however exist challenges on the ability of the quality assurance office to disseminate the regulations of the government and those of Commission of Higher Education to the university departments and users (Figure 1).

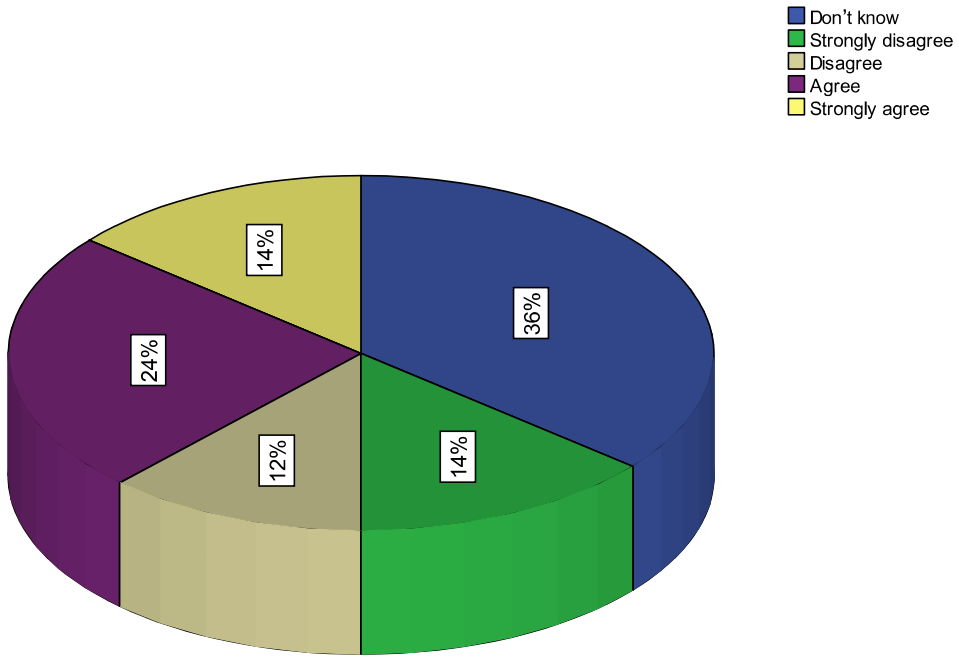


Figure 1: Dissemination of government and CHE regulations to departments

From the study also, 20% of the respondents strongly agree that there exists a feedback between the university and the government while 38% do not know at all of such an interaction. Respondents in this bracket (38%) were students implying that interaction between university and government is not properly communicated or is not known by the students. Only 14% of the respondents strongly

acknowledge the interaction between the university and the industry, 32% agree that the interaction exists while over 30% do not know. Most students again fall in this category and it is therefore apparent that students have limited knowledge of the administrative linkages with the university stakeholders (Figure 2). Even with the policy in place therefore, the interaction between the government, the commission of higher education and the university on quality related issues is still short.

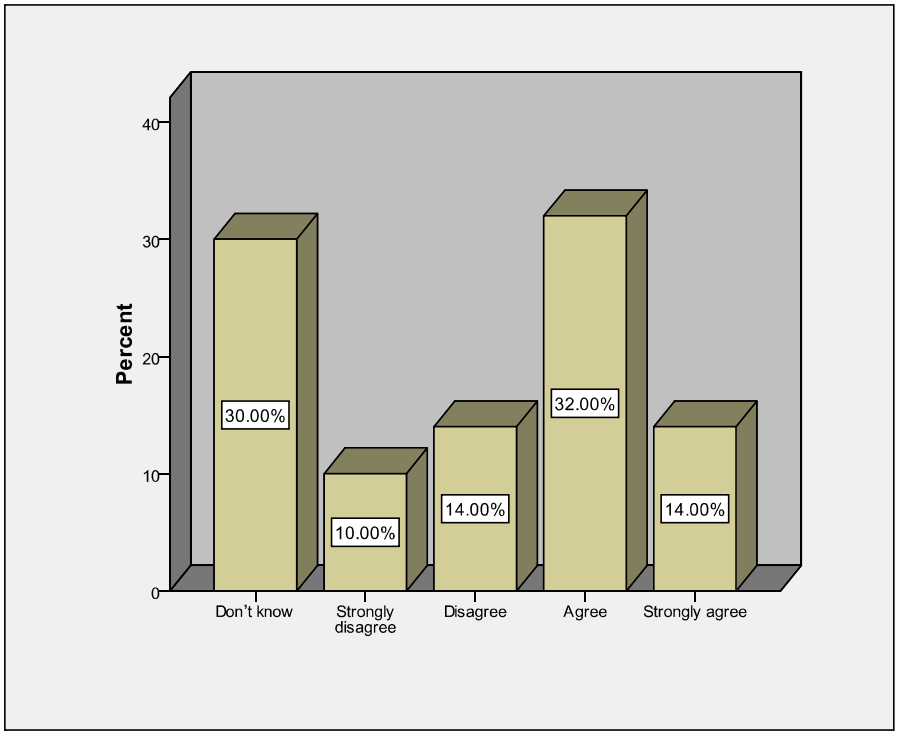


Figure 2: University linkage with the industry/market

4.0 The Effectiveness of Quality Assurance Practices on Teaching and Learning

In ascertaining the effectiveness of quality assurance practices on teaching and learning, questions were asked on the quality practices in place for the students, the practices in place to ensure quality teaching by lecturers, the facilities in place for teaching and learning and the administrative support services provided to students to enhance quality learning in relation to academic trips, attachment supervision, examination processing and academic transcript processing.

The outcome of this study indicated that the existence of clear assessment criteria for students with well understood procedures, rules and regulations emerged as a key strength in JKUAT's quality practices with over 76% agreeing that this practice is effective. The respondents rated clarity of continuous assessment tests at a mean of 3.94[8], the opportunities students are given to give a second opinion of their lecturers at a mean of 3.74 and the effectiveness of student assessment on practicals, assignments and attachment at a mean of 3.8. These scores therefore indicate that JKUAT's student quality assurance practices are effective. However, as similarly pointed out by Ramsden (2003), unless there is effective communication, the impact of the evaluation process on quality of teaching and learning remains challenged. Thus the low score of 2.9 and 2.74 on the way

[8] The interpretation of means is as follows: strongly disagree (1.00-1.8), disagree (1.9-2.7), agree (2.8-3.6), strongly agree (3.7-5.0)

feedback after evaluation is handled and how the recommendations are disseminated indicate an area that JKUAT QA systems should urgently address (Table 1).

Table 1: Students' quality practices

	N	Minimum	Maximum	Mean	Std. Deviation
[9]Students are assessed using clear criteria , regulations and procedures	50	2.00	5.00	4.0400	.83201
The regulations and procedures are applied consistently	50	1.00	5.00	3.7000	1.05463
Feedback is given to students and stakeholders on schedule	50	1.00	5.00	3.4600	1.03431
There is regular meeting between student leaders and university managers	50	1.00	5.00	3.2000	1.16058
There are clear defined lines of communication	50	1.00	5.00	3.0600	1.11410
All students grievances relating to grades or lecturers are handled on time	50	2.00	5.00	3.1400	.96911
The continuous assessment and examination guidelines are clear	50	2.00	5.00	3.9400	.99816
Students assessment is effective	50	1.00	5.00	3.8000	1.01015
The students gets opportunities to evaluate lecturers	50	2.00	5.00	3.7400	1.00631
Feedback on evaluation of lecturers by student is effectively communicated	50	1.00	5.00	2.9000	1.09265
Recommendations on evaluation are effectively are effectively handled	50	1.00	5.00	2.7400	1.02639

The role of lecturers in ensuring quality at universities was positively identified. Their practice of giving assignments and continuous assessment tests as guided by the course objectives, giving of feedback on CATS, meeting the course requirements and attendance of classes received mean scores of 4.38, 4.1, 4.02 and 4.0 respectively (Table 2). The high scores may be as a result of the academic freedom that the faculty staff have been given towards teaching. As also suggested by Bradley (2005), faculty staff do well when left with some level of independence while performing their duties. The results of this study thus affirm and recognize the importance of giving lecturers adequate security from external QA pressures and adequate levels of independence. However, the role of university management in human resourcing, such as the ability to hire and retain the best lectures(mean 3.0) ; to ensure continuous learning(mean 2.6) and to allow lecturers take short courses to increase teaching efficiency (mean 2.36) are issues to be considered. As to whether the university retains the best lecturers in the market, 46% agreed, 28 % disagreed and 26% didn't know.

[9] The interpretation of means is as follows: strongly disagree (1.00-1.8), disagree (1.9-2.7), agree (2.8-3.6), strongly agree (3.7-5.0

Table 2: Lecturer's quality practices

	N	Minim	Maxim	Mean	Std. Deviation
[10]Lecturers meet Course requirements	50	2.00	5.00	4.0200	.74203
Lecturers attend all/most of the classes	50	2.00	5.00	4.0000	.72843
Lecturers communicate clearly and effectively by using examples	50	1.00	5.00	3.6200	.94524
Lecturers are good in presenting material in class	50	1.00	5.00	3.6200	1.00793
Lecturers motivate students	50	1.00	5.00	3.5400	.99406
Lecturers are always available for consultation	50	1.00	5.00	3.3200	.91339
Lecturers administer CATs and assessments as scheduled	50	1.00	5.00	3.9000	.83910
Lecturers give feedback on CATs	50	1.00	5.00	4.1000	.78895
The CATs and assessments are as per course objectives	50	3.00	5.00	4.3800	.56749
There exists mechanisms to ensure on qualified and competed lectures are hired	50	1.00	5.00	2.7800	1.59451
The university encourages continuous learning for lecturers	50	1.00	5.00	2.6600	1.69766
Lecturers are allowed to take short courses to increase teaching efficiency	50	1.00	5.00	2.3800	1.67685
The university maintains the best lecturers in the market	50	1.00	5.00	3.0600	1.54405

The institutional facilities remain generally poor, overstretched and has not been properly matched with the student population. Internet, handling of student academic trips, and library and administrative support to the students were found to be low with mean ratings of 1.28, 1.64, 1.72 and 1.82 respectively (Figure 3)[11]. The disparity of student numbers and facilities over the years has strained the ability of universities to offer quality teaching and learning. This confirms what was earlier observed by Abagi (1999), that in many cases the increase in student numbers over the years is not matched by a corresponding expansion in teaching/learning facilities; Library capacities; resource centres; laboratories; lecture theatres and facilities in halls of residence. The above scores show this to be the case in JKUAT. Therefore, for quality to be assured, JKUAT administration will need to address this disparity. Generally none of the facilities was strongly appreciated by the respondents.

[10] The interpretation of means is as follows: strongly disagree (1.00-1.8), disagree (1.9-2.7), agree (2.8-3.6), strongly agree (3.7-5.0

[11] The interpretation of means is as follows: strongly disagree (1.00-1.8), disagree (1.9-2.7), agree (2.8-3.6), strongly agree (3.7-5.0

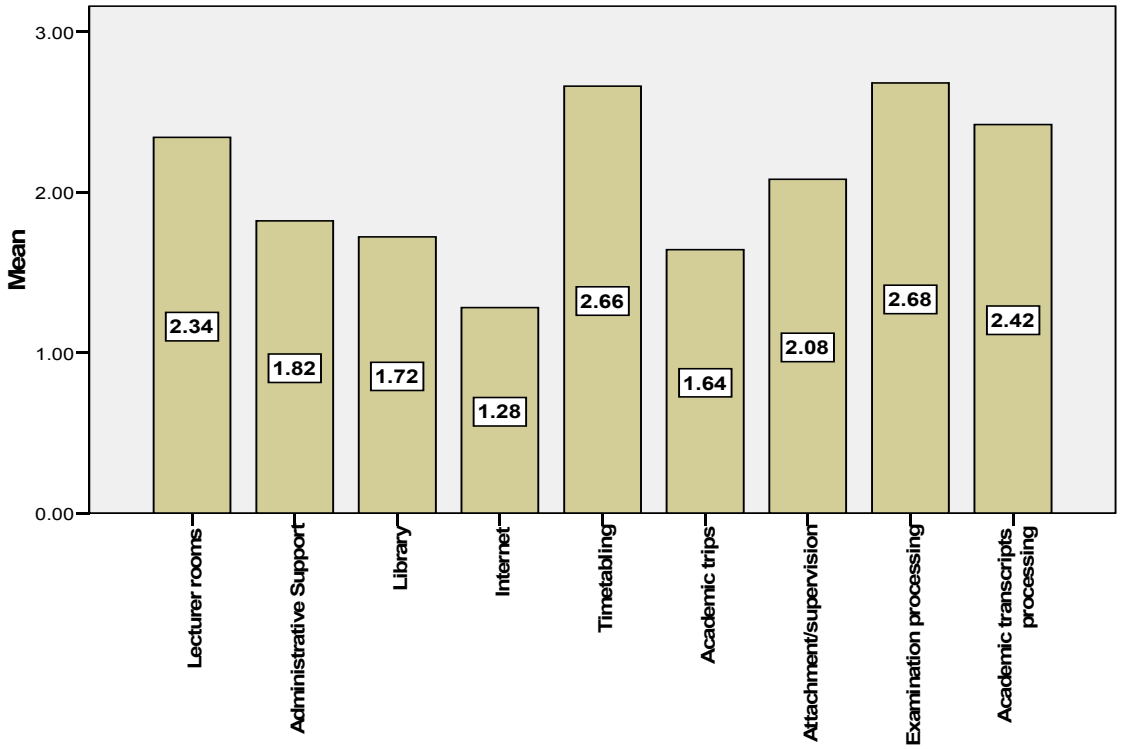


Figure 3: Institutional facilities/services

5.0 Challenges on Quality Assurance

From the study, political interference (mean of 3.26), unregulated entry requirements for some programmes (mean of 3.2) and the inequity, economic disparities and social differences (mean of 3.24) were given as the major challenges to quality assurance (Table 3). These disparities compromise quality at the university as it struggles for economic survival while at the same time balancing possible quality practices. The presence of many quality assurance bodies (mean of 2.8), financial constraints (mean of 2.6) and mushrooming of new universities in Kenya (mean of 2.76) have not however highly negated quality assurance at JKUAT.

As supported from the study, brain drain is real and lecturers are moving to the other universities in search of green pasture, with 38% of the respondents agreeing that JKUAT is facing internal brain drain. The biggest has been the movements of lecturers to the constituent colleges that offer more attractive terms or that take the staff on higher grades than previously occupied. Therefore the assumption that both developed and developing economies compete fairly in an open market for human capital, and that developing countries have equal chances of attracting highly skilled human capital remains challenged from these results. The growing mobility of academics, professional and skilled workers, especially given the usually less attractive terms and conditions of service, salary structures and work environments has really impacted on public universities in Kenya as found in this study.

Table 3: Quality assurance challenges

Item	N	Minim	Maxim	Mean	Std. Deviation
[12]The presence of many quality assurance bodies causes confusion at JKUAT	50	1.00	5.00	2.88	1.23949
The university is challenged whether to follow regional or international quality guidelines	50	1.00	5.00	2.70	1.11117
There is no clear guidelines on institutional quality assurance	50	1.00	5.00	3.04	1.36964
QA at JKUAT affected by Financial limitations	50	1.00	5.00	2.60	1.29363
Professional expertise on quality assurance is missing in JKUAT	50	1.00	5.00	3.16	1.47579
There is communication deficiencies on QA	50	1.00	5.00	3.14	1.38520
There is a lot of political interference on QA	50	1.00	5.00	3.26	1.41147
Regulations of cross border higher education is a challenge to JKUAT	50	1.00	5.00	3.04	1.38446
The unregulated entry requirements for some programmes is a challenge	50	1.00	5.00	3.20	1.29363
The inequity, economic disparities and social differences between universities is a challenge	50	1.00	5.00	3.24	1.43655
JKUAT is facing brain-drain out of the many universities coming up in Kenya	50	1.00	5.00	3.00	1.56492
Mushrooming of new and private universities in Kenya affect s quality assurance at JKUAT	50	1.00	5.00	2.76	1.61068

6.0 Conclusions

Given the findings of this study, universities need to face the challenges with their existing strengths and look at them as opportunities for advancement of knowledge .The disparities as result of brain drain, facilities, feedback mechanisms and financial challenges must well be balanced to ensure public universities, have in place quality assurance practices that stand the test of the current market liberalization and globalization. To ensure effective quality practices, a balance on the demand for higher education; the ability of the Government to finance higher education; the Commission for Higher Education's contribution and the capabilities of institutions of higher learning must be undertaken. this will ensure that admissions into universities is pegged on the existing enabling facilities and resources to avoid overstretching the established libraries, internet and other teaching and learning facilities as found out in this study.

The findings of this study also provides for the need for managers to think beyond the box and develop appropriate human resource development practices that will create conducive and attractive work environment for highly motivated staff. This will address the gaps associated with the rising student numbers and less financing by the government.

7.0 Recommendations

For effectiveness to prevail, universities need to ensure that standards and procedures are adhered to, through a combination of all the key factors including adherence to the quality policy; proper linkages of the policy to other stakeholders contribution; involvement of students in the system; recognition of human capital and the need for continuous development; matching of facilities and service to customer base; and embracing of the challenges as opportunities for the better tomorrow.

It is necessary that there be policies, procedures, and systematic actions within the university for the purpose of providing, maintaining and enhancing quality and accuracy throughout the life cycle of

[12] The interpretation of means is as follows: strongly disagree (1.00-1.8), disagree (1.9-2.7), agree (2.8-3.6), strongly agree (3.7-5.0

the university processes. JKUAT will also need to address the areas that were identified as weak such as inadequacy of facilities; threats as a result of new private and public universities; political intervention; the effects of cross border and transnational education; the challenges associated with attraction and retention of competent staff and the increasing demands of students for academic trips, and special administrative support.

More research on quality assurance in the university is necessary. The increasing demand for university education and the opening of the public universities to run fee paying programmes as a means of self-sustenance has overstretched the existing facilities causing the biggest challenge addressed in this research. This is the same challenge across all public universities because all of them have been forced by circumstances to admit more students because of the big number benefiting from the effect of free primary and subsidized secondary education. JKUAT therefore needs to solicit for more resources to address this challenge of unplanned expansion.

Effectiveness of quality assurance will also be realized when it becomes clear that programmes across the region are standard. Usage of standard quality policy guidelines across universities requires all the programmes to have an equal ground. The diverse entry levels into university programmes in the region are still a challenge and many are the times that Kenyan students cross borders to access the same programmes that they did not qualify for in the country.

References

Abagi, O. (1999). Revitalizing financing of higher education in Kenya resource Utilization in Public Universities in Kenya. Research report, Association of African Universities. Accra, Ghana.

Ajayi, J. F., Goma, L. K. H. and Ampah-Johnson, G. (1996). The African experience with higher education. The Association of African Universities, Accra in association with London: James Currey and Athens: Ohio University Press.

Arcaro, J. S. (1995). Quality in Education. An implementation handbook. Delary Beach, FL: St Lucie Press.

Biggs, J. (2001). The reflective institution: assuring and enhancing the quality of Teaching and learning. *Journal of Higher Education,* **41**, pp 221-238.

Billing, D. (2004). International comparisons and trends in external quality assurance: commonality or diversity. *Journal of Higher education,* **47**, pp 113-137.

Billing, D. and Thomas, H. (2000). The international transferability of quality assessment systems for higher education: The Turkish experience. *Quality in higher education*, **6** (1), pp 31-40.

Bradley, D. A. O. (2005). To what End? The Effectiveness of Quality Assurance in Higher Education. Biennial Conference on Quality, Assurance and Diversity.

Carrington, W. J. and Detragiache, E. (1999). How Extensive Is the Brain Drain. *Journal of Finance and Development.* **36**, pp 46–49.

Dolinsek, S., and J. Rupnik. (1999). Realizing the European higher education area. Communiqué of the Conference of Ministers responsible for Higher Education in Berlin. 19 September 2003.

El-Khawas, E. (2001). Who's in charge of quality? The governance issues in quality assurance. *Tertiary Education and Management,* **7**, pp 111-119.

Evans, J. R. and Lindsay, W. M. (1996). The Management and Control of Quality. West Publishing Company.

Farrugia, C. (1996). A continuing professional development model for quality assurance in higher education. *Journal of quality assurance in education,* **4**(2), pp 28-34.

Galloway, L. (1996) .But which quality do you mean*? Quality World*, pp.564-8.

Gabko, P., Osanna, P. H., & Reichl, F. (2000). Quality Management and Total Quality at Universities. Workshop Proceedings. Dept. Interchangeable Manufacturing and Industrial Metrology – Austauschbau und Messtechnik, ISBN 3-901888-15-2.

Gordon, G. (2002). The roles of leadership and ownership in building an effective quality culture. *Quality in Higher Education'*, **8**(1) pp. 97-106.

Harvey, L. (2001). Evaluation for what?. *Quality in Higher Education*, 7(3), 245-263.

Harvey, L. (2002). The end of quality. *Quality in higher education*, 8(1), 5-22.

Hoyle, D. (1995). ISO 9000 Quality Systems Handbook. Butterworth-Heinemann Ltd, Oxford, pp.415.

Huba, M. and Freed, J. (2000). Learner-centred assessment on college campuses. Boston: Allyn and Bacon.

Magagula, C. M. (2005). The Benefits and Challenges of Cross-Border Higher Education in Developing Countries. *JHEA/RESA*. **3**(1), pp 29–49.

Maviiri, J.C. (2007). *Trading or Sharing – Emerging opportunities and challenges for Cross Border Higher Education in East Africa*. Retrieved May 20, 2009, from http:// www.iau.iau.net.conferences. Nairobi: Kenya.

Ministry of Education Science & Technology (2006). Kenya Education Sector Support Programme. Delivering quality education and training to all Kenyans. Nairobi.

Mugenda, O. M. and Mugenda, A. G. (1999). Research methods; quantitative and Qualitative approaches. Nairobi: African Centre for Technology Studies.

Nafukho, F. M. (2004). The market model of financing state universities. African Universities in the Twenty-First Century,Vol. 1: Liberalisation and Internalisation, Dakar: CODESRIA, pp 126–39.

Newton, J. (1999). An evaluation of the impact of external quality monitoring on a higher education college., *Assessment and Evaluation in Higher Education*, **24**(2), pp. 215-235.

Newton, J. (2000). Feeding the beast or improving quality. academics perceptions of quality assurance and quality monitoring. *Quality in Higher Education*, **6**(2), pp.153-163.

Newton, J. (2002). Views from below: academics coping with quality. Quality in Higher Education**,** **8**(1), pp.39-61.

Ngware, M. W., & Ndirangu, M. (2005). An improvement in instructional quality: can evaluation of teaching effectiveness make a difference. *Quality Assurance in Education.* 13(3), 183 – 201. ISSN: 0968-4883.

Ramsden, P (2003). Learning to teach in higher education, *Routledge Falme*. (2nd ed.) London.

Scott, P. (2000). Globalization and the University: Challenges for the Twenty- First Century. Centre for Higher Education Transformation.

Scott, G. and Hawke, I. (2003). Using an external quality audit as a lever for institutional change. *Assessment and evaluation in higher education,* **28**(3).

The Universities Act, Cap 201B (1985). Special Issue of the Kenya Gazette Supplement No. 65 of 15th October, 2004 (Legislative Supplement No. 41).

Legal Notice No. 112. Retrieved January 15, 2009, from http:// www.che.or.ke.

Vidovich, L. (2001). That chameleon 'quality': The multiple and contradictory discourses of 'quality' policy in Australian higher education. *Discourse: studies in the cultural policies of education*, **22**(2), pp 249-261.

World Bank (1988). Education in Sub-Saharan Africa: Policies for Adjustment, Revitalisation and Expansion. Washington, DC: World Bank.

World Bank (2000). Higher Education in Developing Countries: Peril or Promise. Task Force on Higher Education and Society. Washington DC: World Bank.

World Bank (2002). Constructing Knowledge Societies. New Challenges for Tertiary Education. Washington, DC: World Bank.

Yizengaw,T.(2003). Transformations in Higher Education: Expansion in Ethiopian Higher Education System. Regional Training Conference on Financials, 23–25 September, Accra, Ghana.

CAN MACROECONOMIC INDICATORS BE USED AS PREDICTORS OF THE STOCK EXCHANGE INDEX TRENDS? A LOOK AT THE NAIROBI STOCK EXCHANGE

S. W. Muthike and M. M. Sakwa
Jomo Kenyatta University of Agriculture and Technology, Nairobi
E-mail: serahwagio@gmail.com

Abstract
The factors influencing the investor's decision to invest in the Stock Exchanges are well documented, yet an investor cannot consistently maximise returns and minimise risks. The literature mainly focuses on the individuals as investors and their reactions to statements from the respective firms or experts or the government projections (political or economic). What is not very certain in literature are the potential effects that macroeconomic Indicators on the stocks exchange index trends. The implication of this is that there are relationships between the stock exchanges index levels and the Macroeconomic Indicators such as inflation rate, money supply among others, that even if they do not directly impact on the index levels of the stock exchanges, they influence individuals to either increase or decrease their portfolios. On this basis, the study investigated the relationships between Nairobi Stock Exchange index trends and the Macroeconomic Indicators in the country. Correlations can either be positive or negative but more importantly when the correlations between the NSE index trends and the Macroeconomic Indicators are either leading, or lagging, they can inform the investors to either increase or decrease their portfolios thus aiding the maximization of returns and the minimisation of risks. The data was gathered from Nairobi Stock Exchange (daily market reports), Kenya National Bureau of Statistics (Statistical Abstracts) and the Central Bank of Kenya (Monthly Economic Reports).The coefficients for the logarithms of treasury bills, money supply, and real exchange rates were positive, while the signs of Inflation Rates and Gross Domestic Product were negative. The 91-Day Treasury Bills and the Inflation rate were the only clear Leading Macroeconomic Indicators on the NSE 20-Share Index. The money supply and real exchange rates showed that they were both leading and lagging Macroeconomic Indicators on the NSE 20-Share index. Hence they cannot be used to proxy the share prices. The gross domestic product showed the weakest relationship with the NSE 20-Share index. The study concludes that the Kenyan stock market and the formed significant relationships with all Macroeconomic Indicators identified, except the gross domestic product.

Key words: Nairobi stock exchange index trends, macroeconomic indicators

1.0 Introduction

Under the Arbitrage Pricing Theory (APT), it is implied that Macroeconomic variables may proxy for pervasive risk factors in the economy, Roll and Ross (1986). However, literature has ignored the potential impact that macro economic variables have on the emerging stocks market. Chen *et al*., (1986) have argued that stock trends should be affected by any factor that influences future cash flows or the discount rate of those cash flows of which macroeconomic factors are part. Fama (1970) and McDonald (1986) generally in their empirical studies, found a significant relationship between changes in macroeconomic variables such as gross domestic product, inflation, money supply, interest rates yield, foreign exchange rates and the stock trends.

This therefore suggests that a wide range of factors may be relevant in determining the stock trends. Such variables include and not limited to goods and services prices, money supply, real activity, foreign exchange rates, interest rates, political risk, unemployment/employment levels, export earnings, regional stock market indices, broadband internet penetration, regional retail sales, bankruptcies. Krugman (1995) talks of emerging stock markets in which case there is an argument, that not all these variables are either relevant or appropriate. For instance, in emerging stock markets, there is not an active online secondary market for bond issues and government paper trading. Political risk indices, bankruptcy and oil prices have shown to weakly correlate with the emerging stock markets returns; regional influences on retail sales are expected to be incorporated into returns if countries are integrated regionally, but the theoretical justification for the empirical link is limited. Moreover, such a link is likely to be driven by fundamental macro factors and a regional index is only useful to the extent that it captures the underlying fundamentals; the unemployment/ employment levels are usually realised after every decade and so is the broad band internet penetration. Hence, at this stage these variables are excluded as the macro economic factors of interest to this study.

In the Kenya's case international investors have been attracted by the good rating of Kenya stock market by the Standard and Poor rating agency which rated Kenyan foreign debt as investment grade B+ and domestic debt as BB- which means that the foreign investors can confidently invest in Kenya equities and bonds (Capital Market Authority, 2006). The implication is that the Nairobi stock exchange is now more vibrant and there is the need to find ways of ensuring it remains attractive to both the domestic and the international visitors. Techniques to help investors get positive returns need to be found. This will create confidence on the investors to trade in stocks thereby mobilizing the necessary funds for development and industrialization. To create this confidence requires an understanding of the macro variables that impact on the wealth creating activities the firms listed in these stock exchanges and if these variables can be utilized to predict the stocks trends.

Can an investor consistently beat the market in an efficient market so as to have positive returns always? The answer is no according to efficient market hypothesis (EMH). According to Fama (1970), share prices reflect all currently available information and that it is impossible for an investor to consistently outperform the market since all information will already have been reflected in the security prices. However, over time investment advisors have been shown to rely not only on fundamental analysis for investment decisions but also on technical analysis. There is no sure method to predict share prices so as to outperform the stock market. Investing involves risks, and so investors should invest their money based on the quality of their investments.

Based on the above analysis, is it then important to investigate the relationship between the NSE 20-Share index trend and trends in the Macroeconomic Indicators such as the exchange rates, gross domestic product, money supply, interest rates and inflation rates? The critical question here is whether an investor can make an investment decision based on the leading or lagging trends of Macroeconomic Indicators on the stock exchange index trend? This study investigated the above

questions with the objective of recommending the trends in the local stock market on the basis of which investors and their advisors can make informed stock market investment timing decisions.

2.0 The Stock Exchange Indices and the Economy

This Section aimed to review literature related to the objectives of the research project. It intends to shed light on the research hypothesis. The purpose of this literature review is to examine what other researchers have already written about the NSE 20-sShare index and macroeconomic indicators in general.

The strength that stock trends affect the economy can be seen by the fact that as opposed to other businesses that require huge capital outlay, investing in shares is open to both the large and small stock investors because a person buys the number of shares they can afford. Therefore the stock exchange provides the opportunity for small investors to own shares of the same companies as large investors. Governments at various levels may decide to borrow money in order to finance infrastructure projects such as sewage and water treatment works or housing estates by selling another category of securities known as bonds. These bonds can be raised through the stock exchange whereby members of the public buy them, thus loaning money to the government. All these activities have effects in the economy.

At the stock exchange, share prices rise and fall depending, largely, on market forces. Share prices tend to rise or remain stable when companies and the economy in general show signs of stability and growth. An economic recession, depression, or financial crisis could eventually lead to a stock market crash. Therefore the movement of share prices and in general of the stock indexes can be an indicator of the general trend in the economy. Therefore the relationship between the Stock trends and the economic trends can be argued to be cyclic. This is summarised in Figure 1.0 below.

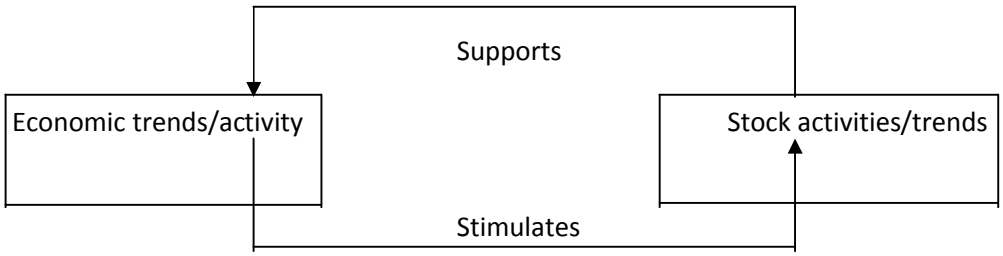


Figure 1: Relationship between stock trends/activities and economic activities/trends

From Figure 1: above, summarizes the relationship between economic trends/activities and the stock trends/activities. The economic trends/activities are usually summarized in macroeconomic indicators while the Stock trends/activities are usually summarized in the stock exchange indices.

The Macroeconomic Indicators selected for this study are deemed to be major according to the Economic Surveys publication of Kenya and the Kenya National Bureau of Statistics both published by the government of Kenya .They are: money supply, inflation rate, treasury bill rate, gross domestic product and the foreign exchange rate. From figure 1 above, the relationship between these Macroeconomic variables and the Stock exchange trends/activities are as shown in the Figure 2.

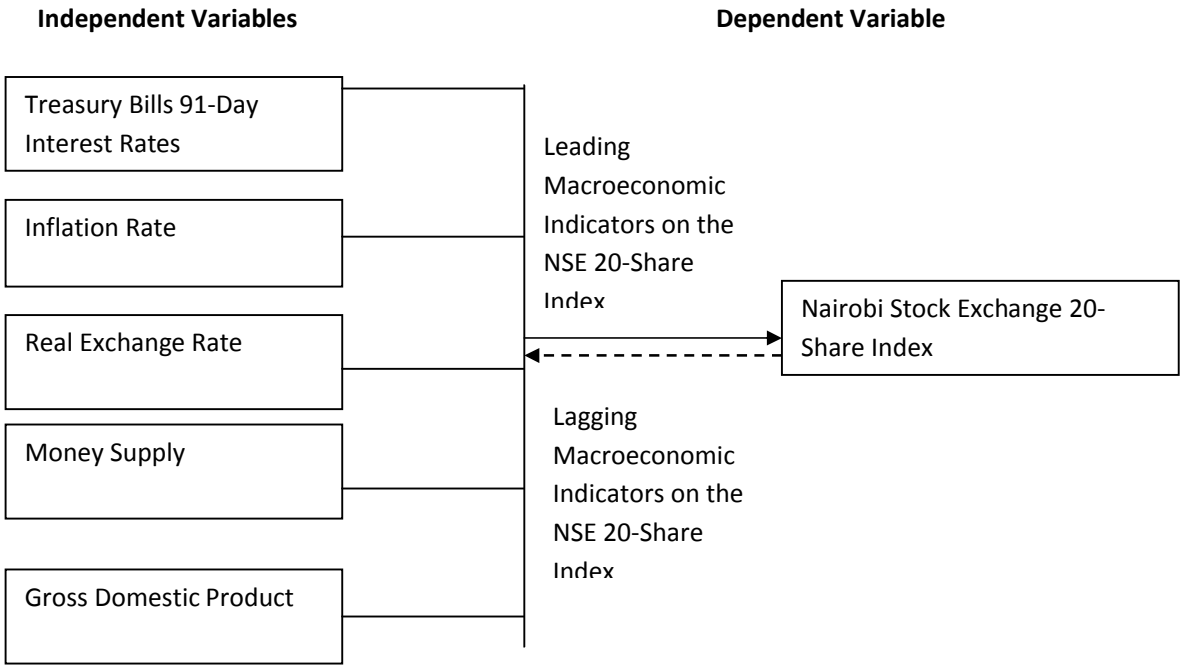


Figure 2: Conceptual framework of the relationship between the macroeconomic indicators and the stock exchange index

As figure 2: above indicates, the objective of this paper was to examine the relationship between the macroeconomic variables and the Nairobi Stock Exchange index trend. The research question was whether the macroeconomic indicators be used as predictors of the stock exchange index trends. To be able to answer this research question, it is necessary to identify the leading and lagging Macroeconomic indicators to the stock exchange index trends. A leading indicator is an economic index intended to forecast future economic activity**.** Lagging indicator is an economic indicator that reacts slowly to economic changes, it follows the trends in economic activities.

Even when stock trends do precede economic activity, a question that arises is how much lead or lag time should the market be allowed. For example, do decreases in Stock trends today signal a recession in six months, one year, two years, or will a recession even occur. Traditionally, correlation coefficients have been used to establish leading or lagging indicator properties. Following Fiorito and Kollintzas (1994), a variable is classified as pro-cyclical if the correlation coefficient is statistically significant and positive or negative. In addition, a variable is classified as leading or lagging, if the maximum absolute cross-correlation value corresponds to a lag or lead of the variable relative to stock market index.

Establishing the lead or lag relationship between Stock trends and macroeconomic variables is important. By knowing these relationship, investors can earn profits by exploiting past information of the variables. In addition, they may be used as indicator to formulate current economic stabilization policies.

The Stock Exchange and the Economy

The stock market has traditionally been viewed as an indicator or "predictor" of the economy. Many believe that large decreases in stock trends are reflective of a future recession, whereas large increases in stock trends suggest future economic growth. The stock market as an indicator of economic activity, however, does not go without controversy. Skeptics point to the strong economic growth that followed the 1987 stock market crash as reason to doubt the stock market's predictive ability. Given the controversy that surrounds the stock market as an indicator of future economic activity, it seems relevant to further research this topic.

Theoretical reasons for why stock trends might predict economic activity include the traditional valuation model of stock trends and the "wealth effect." The traditional valuation model of stock trends suggests that Stock trends reflect expectations about the future economy, and can therefore predict the economy. The "wealth effect" contends that stock trends lead economic activity by actually causing what happens to the economy.

The stock exchange provides companies with the facility to raise capital for expansion through selling shares to the investing public. When people draw their savings and invest in shares, it leads to a more rational allocation of resources because funds, which could have been consumed, or kept in idle deposits with banks, are mobilized and redirected to promote business activity with benefits for several economic sectors such as agriculture, commerce and industry, resulting in stronger economic growth and higher productivity levels of firms. Companies view acquisitions as an opportunity to expand product lines, increase distribution channels, hedge against volatility, increase its market share, or acquire other necessary business assets.

The "wealth effect" is also regarded as support for the stock market's predictive ability. Pearce (1983) argues that since fluctuations in Stock trends have a direct effect on aggregate spending, the economy can be predicted from the stock market. When the stock market is rising, investors are wealthier and spend more. As a result, the economy expands. On the other hand, if Stock trends are declining, investors are less wealthy and spend less this result in slower economic growth.

A takeover bid or a merger agreement through the stock market is one of the simplest and most common ways for a company to grow by acquisition or fusion. Both casual and professional stock investors, through dividends and stock price increases that may result in capital gains, will share in the wealth of profitable businesses. By having a wide and varied scope of owners, companies generally tend to improve on their management standards and efficiency in order to satisfy the demands of these shareholders and the more stringent rules for public corporations imposed by public stock exchanges and the government. Consequently, it is alleged that public companies (companies that are owned by shareholders who are members of the general public and trade shares on public exchanges) tend to have better management records than privately-held companies (those companies where shares are not publicly traded, often owned by the company founders and/or their families and heirs, or otherwise by a small group of investors). Therefore in normal circumstances on the application of good governance perspective and prudent decisions it is possible that the stock crashes when Stock trends are bullish will be an exception rather than a rule.

There are a number of some well-documented and known cases where it is alleged that there has been considerable slippage in corporate governance on the part of some public companies. The dot-com bubble in the early 2000s, and the subprime mortgage crisis in 2007-08, are classical examples of corporate mismanagement. Companies like Pets.com (2000), Enron

Corporation (2001), One.Tel (2001), Sunbeam (2001), Webvan (2001), Adelphia (2002), MCI WorldCom (2002), Parmalat (2003), American International Group (2008), Lehman Brothers (2008), and Satyam Computer Services (2009) were among the most widely scrutinized by the media.

2.2 The Stock Trends and the Macroeconomic Indicators

money supply, inflation rate, treasury bill rate, gross domestic product and the foreign exchange rate as summarized by figure 2 and supported by the discussion in the section above do have a relation with the stock exchange index. The trends in these macroeconomic variables have the effect of acting as motivating or indicators for investors to trade in stocks.

2.3 Inflation

Inflation, along with interest rates are important variables for determining the required rates of return used to derive the value of investments (Reilly, 1994). Thus, one would expect inflation to have some impact on Stock trends. In this connection, Kaul (1990) notes that research evidence from the four major economies (i.e., U.S, Canada, UK and Germany) show a very significant negative relationship between stock trends and changes in the expected inflation. This evidence further revealed that this negative relationship varies systematically depending on whether the monetary authority is using interest rate or money supply as leverage in controlling inflation. The relationship was much stronger during interest rate regime (i.e., when interest rate is used to control inflation) than during money regime (supply is used to control inflation).

Kannianen and Kurikka (1984) supported this theory of negative relationship between Stock trends and inflation, by noting that generally, inflation is taken as "bad news" for the stock market; that is, when inflation rises, Stock trends should fall since inflation erodes people's wealth, hence reduces their propensity to invest. Hasbrouk (1984) reached the same conclusion on the negativity of the relationship between stock trends and inflation, in his empirical study of the relationships between stock trends, inflation and the economic activity. However, Kwon, C. (1997) in his empirical study of the effects of macro economic variables on stock trends in developing markets contradicts this finding and states that inflation and interest rates related variables are not significant factors to the Korean market.

2.4 Interest Rates

Interest rates act as the cost of the capital to companies. They are also returns on the alternative assets, such as savings accounts and treasury bills. As the cost of capital, interest rates influence the profitability and the value of the quoted companies; for if a company pays a very high interest rate on its debt capital, then its earnings potential will be eroded, hence investors will mark down its value. A report in the fortune magazine November, 1997 analyzing the swings in the US stock market note that higher interest rates make a company's potential future earnings to look less attractive, therefore, "the value of the company and the stock price should be adjusted downwards". Interest rates also reported by the Japan Securities Research Institute 1996 to be among the three most important factors affecting the fluctuations in Stock trends in the Japanese market. The other two factors being, corporate earnings and business cycle trends

2.5 Exchange Rates

Ma and Wenchi (1990) on their part examined the reactions of the Stock trends to changes in the exchange rate. They noted that due to the internationalization of the financial markets, there is increasing risk for international investments, and therefore the choice of the currency denomination was important. From their study they concluded that changes in a country's exchange rate had two possible effects on the Stock trends movements: firstly the financial effect of the transaction

exposure investors would face if the underlying currency is volatile and secondly the economic effect, which works through making exports competitive or non-competitive. If a country is export-oriented and its currency appreciates, it reduces the competitiveness of its exports, and would, therefore, have a negative impact on the domestic stock market. This is because the quoted companies in the stock market, which are exporters, would be less profitable, thus less attractive to investors. The opposite would be true if the currency depreciates making exports competitive e.g. coffee boom in 1992.

2.6 Gross Domestic Product

It is widely accepted that current stock levels are positively related to future levels of real activities as measured by Gross Domestic Product (GDP) or industrial production. Intuitively this finding seems justified since returns are a function of the future economic conditions. However a number of studies have documented a relationship between past, current production and stock trends, Fama (1970, found a relationship between the concurrent measures of the United States of America (U.S.A.), stock trends and industrial production that was positive and highly significant. Tobin (1985) investigated the relationship between the lagged change in U.S.A.'s industrial production and the return on the Standard and Poor 500 index using the monthly data 1962 and 1981. They found that current stocks returns were related to industrial production lagged by two periods.

2.7 Money Supply

There are several justifications to expect a relationship to exist between the Macroeconomic Indicators and stock trends. Exploring each indicator in turn; monetary portfolio theory suggests that changes in money supply alters the equilibrium position of money, thereby altering the composition and price of assets in an investor's portfolio. In addition, changes in money supply may impact on real economic indicators thereby having a lagged influence on stock trends, Rogalski and Vinso (1977). Both of these mechanisms suggest a positive relationship between changes in money supply and stock trends.

2.8 The Research Gap

The studies above have failed to uncover the relationship between the NSE 20-Share index trend and the Macroeconomic Indicators. They have also failed explain the leading or lagging Macroeconomic Indicators on then NSE 20-share index trend. This study aimed to fill this gap. Growth performance of developing countries over the past decades has been both unsatisfactory and uneven, often accompanied with sharp declines in investments such declining trends in investments have had great effect on the economy (Jordan, 1991).

3.0 Methodology

3.1 Research Design

This study used available data namely the Nairobi Stock Exchange (NSE) 20 share index and the macroeconomic Indicators as provided by the Central Bank of Kenya and the Kenya National Bureau of Statistics economic surveys publications. These data's were organized on a yearly basis and the included macroeconomic indicators are considered as the major ones for the Kenyan economy. The study was quantitative involving the use of statistical and quantitative techniques to answer the study hypotheses. The NSE 20 share index incorporates 20 companies cutting across all the 5 sectors in the economy namely the industrial and allied sector, agricultural sector, commercial and services sector, alternative investment sector and the financial sector in its calculations.

3.2 Data Source and Description

For the purposes of observing the relationship between the performance of the stock market index trend and the macro-economic indicators of inflation, exchange rates, interest rates, industrial production and money supply, the data was organized into yearly basis. This was found suitable

because all the variable trends as provided by the Central Bank of Kenya and the Kenya National Bureau of Statistics are organized into yearly averages. For consistency purposes, the returns from the NSE are also to be computed on a monthly and yearly basis. The yearly data statistics covers the period December 1976 to December 2008. This was deemed a long time enough to observe consistent trends in the variables. The period was also relevant because it incorporated the periods when NSE has seen mixed performances. During this period it performed both poorly as well as excellently. The long span data were exposed to various policy changes and economic shocks that may induce structural shifts and therefore the period will entail 33 years from December 1976 to December 2008. This data organization gave 33 data points for each of the six variables in the study (i.e. the NSE Share index, the Inflation Rate, the Treasury bill, Gross Domestic Product, Money Supply and the Real Exchange Rate). For evaluation purposes, the data points exceeded 30 hence considered to be normally distributed for statistical examination. This data sources are summarized in Table 1.

Table 1: Data source

Description	**Units**	**Source**
Nairobi stock exchange 20 -share index	points base Jan 1966=100	Nairobi Stock Exchange
Principal rate composite currency)	(percentage per annum	Kenya National Bureau of Statistics
91-day Treasury Bill rate	percentage per annum	Kenya National Bureau of Statistics
Gross domestic product	percentage per annum	Kenya National Bureau of Statistics
Money supply	Millions of Kenya Shillings	Central Bank of Kenya
Inflation rate	percentage per annum	Kenya National Bureau of Statistics

3.3 Data Analysis

The analysis involved two stages; the first stage established the relationship between the stock market index trend (NSE 20-share) and the individual macroeconomic indicators of real exchange rates, treasury bill 91-day interest rates, money supply, gross domestic product and inflation rates. the data was collected, input in an excel spreadsheet coded and exported to a spss 12.0 where it involved computation of a correlation coefficient between the NSE 20 share index trend and each of the macroeconomic indicators. This involved the use of Pearson product moment correlation analysis for each of the macroeconomic Indicators against the NSE 20-share index. The reason for using Pearson product moment correlation technique was because the secondary data collected was continuous.

Correlation analysis helps to identify any existing relationships between two variables and also determining the strength and directions of association between two variables is very important

because this piece of information forms the basis for selecting the variables for further statistical analysi, e.g. regression analysis (Mugenda, 2003). The next stage involved plotting graph between the NSE 20-share index and all the five Macroeconomic Indicators against time to determine any leading or lagging Macroeconomic Indicators on the NSE 20-share index trend. The Z-test was to be used due to the fact that the data was more than 30 with a significance level of 1%. The following hypotheses were formulated to act as guidelines in the analysis of data:

Research question
Can the macroeconomic indicators be used as clear predictors of the stock trends?

To answer this research question, the following hypotheses were formulated;

H_{01}: There is no relationship between the NSE 20-Share index and the macroeconomic indicators.
H_{A1}: There is a relationship between the NSE 20-Share index and the macroeconomic indicators.

H_{02}: There are no leading macroeconomic indicators on the trends of the NSE 20-share index.
H_{A2}: There are leading macroeconomic indicators on the trends of the NSE 20-share index.

H_{03}: There are no lagging macroeconomic indicators on the trends of the NSE 20-share index.
H_{A3}: There are lagging macroeconomic indicators on the trends of the NSE 20-share index.

Statistical Conventions
These were be used interchangeably throughout the rest of this section. Statistical package for the social sciences (SPSS 12.0) was used to run the correlation analysis. It was done in four stages, namely:
( ) With time period of zero (n=0), meaning that changes in the explanatory variables impact on the stock index concurrently that is $S_{(t)} = M_{(t)}$
(i) With a time period of one (i.e. n=1); Base year being 1976 hence one year before i.e.($S_{(t)} = M_{(t-1)}$) and one year after 1976 i.e. $S_{(t)} = M_{(t+1)}$.
(ii) With a time period of two (i.e. n=2); Base year being 1976 hence two years before i.e.($S_{(t)} = M_{(t-2)}$) and two years after 1976 i.e. $S_{(t)} = M_{(t+2)}$.
(iii) With a of time period of three (i.e. n=3); Base year being 1976 hence three years before i.e.($S_{(t)} = M_{(t-3)}$) and three years after 1976 i.e. $S_{(t)} = M_{(t+3)}$.

The Z-test was to be used due to the fact that the data is more than 30 with a significance level of 1%. The null hypothesis is rejected when the correlation coefficient is zero at 1% significance level. The decision of whether to use a one- or a two-tailed test was important because a test statistic that falls in the region of rejection in a one-tailed test may not do so in a two-tailed test, even though both tests use the same probability level.

Whereby $S_{(t)}$ means the Nairobi Stock Exchange 20-Share Index at a time period which is 1976.
$M_{(t)}$ means the macroeconomic indicators at a time period t starting 1976-2008.
$M_{(t-1)}$, $M_{(t-2)}$, $M_{(t-3)}$; shows that the NSE 20-Share index that correlate with the macroeconomic indicators hence showing leading trends.

$M_{(t+1)}$, $M_{(t+2)}$, $M_{(t+3;}$ shows that the NSE 20-Share index that correlate with the macroeconomic indicators hence showing lagging trends.

4.0 Results and Discussion

4.1 Test of Hypotheses

To assess the relationship between the stock market index trend (NSE 20-share index) and the individual macro-economic variables of exchange rates, interest rates, money supply, gross domestic product and inflation rates; a computation of a correlation coefficient between the NSE 20-Share Index trend and each of the macroeconomic variables on spreadsheet software was done. Usually a correlation coefficient yields a statistic that ranges from -1 to +1. It applies to 1% significance level. A strong relationship is detected when the correlation coefficient yields a statistic that is close to -1 or +1, while a weaker or no relationship is detected when the correlation coefficient yields a statistic that is close to zero or zero. Generally, the null hypothesis in this study for instance indicating no relationship between the NSE 20 share index and macroeconomic indicators is rejected if the p-value is less than 0.05 or 0.01, corresponding to a 5% or 1% chance respectively of an outcome not occurring. The lags are computed to check the point at which the leading macroeconomic indicators denoted by $S_{(t)} = M_{(t-n)}$ or the lagging Macroeconomic Indicators denoted by $S_{(t)} = M_{(t+n)}$ have a relationship with the stock index.

4.2 Relationship between the NSE 20-Share Index and the Macroeconomic Indicators

Concentrating primarily on the US stock exchanges, such early studies attempted to capture the effects of economic forces in a theoretical framework based on the Arbitrage Pricing Theory (APT) developed by Ross (1976). The APT essentially seeks to measure the risk premia attached to various factors that influence the returns on assets, whether they are significant, and whether they are "priced" into stock market returns. Accordingly, Chen, Roll and Ross (1986), having first illustrated that economic forces affect discount rates, the ability of firms to generate cash flows, and future dividend payouts, provided the basis for the belief that a long-term equilibrium existed between Stock trends and macroeconomic variables.

Generally, it can be the case that the relationship between the macroeconomic indicators and the stock exchange are not necessary linear as a correlation analysis may require. To overcome this shortcoming the data was transformed to natural logarithms so that to make the data have homogeneity on all the variables. In inferential statistics, the logarithm of the data in a dataset can be used for parametric statistical testing if the original data do not meet the assumption of normality and linearity.

After the data was transformed to natural logarithms the trend of the relationship between the Nairobi Stock Exchange 20-share index and the macroeconomic indicators was visible, figure 3. The figure shows the plots of the relations between the NSE 20-Share index and the macroeconomic indicators. The claim that there is a relationship between the Stock trends and the macroeconomic indicators can be deduced from the figure below where the behavior of the NSE 20-Share index and the macroeconomic indicators seem to be correlating.

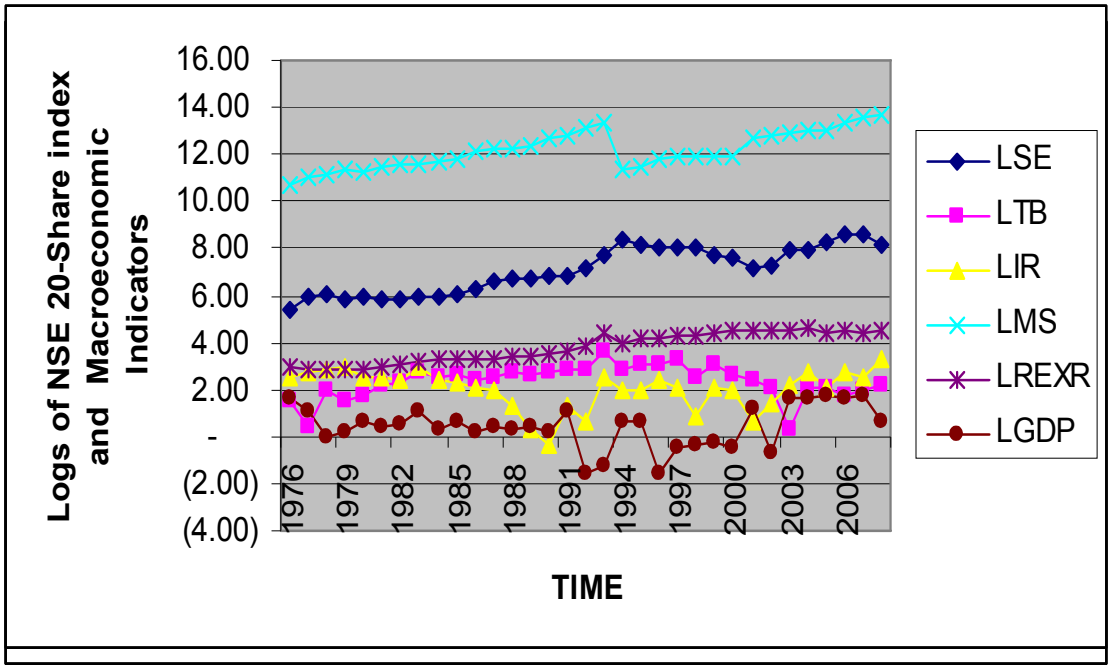


Figure 3: Relationship between the NSE 20-Share index and macroeconomic indicators

On the relationship between the NSE 20-Share index and the macroeconomic indicators, the following hypothesis guided the study:

H_{01}: There is no relationship between the NSE 20-Share index and the macroeconomic indicators.
H_{A1}: There is a relationship between the NSE 20-Share index and the macroeconomic indicators.
Where **H_0** means the null hypothesis and **H_A** means alternative hypothesis.

The p-Value approach to Hypothesis testing was used. The p-values returned to the tests were compared to the significance level (α) which was set at 0.01. The statistical decision rule is; if p-value is greater than or equal to the significance level (p-value≥α) the Null Hypothesis is not rejected. Else, if the p-value is less than the significance level (p-value≤α), the null hypothesis is rejected.

Table 2: Relationship between the NSE 20-Share Index and the macroeconomic indicators with a period time of zero

		LSE	LTB	LIR	LMS	LREXR	LGDP
LSE	Pearson Correlation	1	.227	-.064	.618(**)	.913(**)	-.014
	SSig. (1-tailed)	.	.102	.363	.000	.000	.470

** Correlation is significant at the 0.01 level (1-tailed).
a Listwise N=33
From the above table, the relationship between the Nairobi Stock Exchange 20 share index and inflation rate, treasury bills and the gross domestic product were not significant at 1% being -0.064, 0.227 and 0.014 respectively. The relationship of the NSE 20-share index and money supply was significant at 1% significance level with 0.618 coefficients. At 1%, the Real exchange rate showed the

greatest relationship with the NSE 20-Share index at 0.913 coefficients. The highest and significant relationship was between the NSE 20-Share index and real exchange rate. Therefore only the money supply and the real exchange rates had a relationship with the NSE 20-Share index.

The strong, significant positive correlation between the exchange rate and the NSE 20-share index can be interpreted from the perspective that Kenya is an export dependent country. This can be understood from the fact that the biggest foreign exchange earners and wealth creating products are exports such as tea, coffee, horticultural products among others in addition to tourism. These products are sensitive to the exchange value of the currency relative to other currencies. The positive correlation confirms that when the NSE 20-share index rises the currency will depreciate thereby supporting exports. This basically means that the country will have extra incomes that can be put used for investment.

The positive correlation between the NSE 20-share index and money supply can also explained in terms of exports. As the country exports there resultant profits increases money supply in the economy. This implies that there is excess money in the economy which is used now for investment purposes (see Sakwa 1996). However, at present or since the 1990s it can be argued that money supply in Kenya is not only a factor of export earning but also due to the possibilities of individuals' ability to raise funds through the liberalized financial system. This was for example seen during the launch of the Safaricom IPO. This subsequently implies that trade in stocks is well embraced in Kenya where people hope to cash in on dividends from their stocks.

The practicality of establishing this relationship between the NSE 20-Share index and the macroeconomic indicators is that the Kenyan investors behave in a 'herding behavior' where they invest in regard to what other investors are doing instead of examining the economy to make a decision on their investments. This was evident in huge buying Safaricom shares, then followed the decline in the investment of Cooperative bank shares (under-subscription) since most investors suffered loses in the oversubscription of the Safaricom shares, then when the Kengen bond offer came it was again over-subscribed. This means that the investors need to be enlightened on how the economy is performing in order to maximize returns and minimize risks.

4.3 Leading macroeconomic Indicators on the Nairobi Stock Exchange 20-share Index at a Time Period (s(t) =m(t-n))

A Leading indicator is an American economic index intended to forecast future economic activity. The procedure for testing statistical causality between Stock trends and the economy is direct "Granger-causality" test (Granger, 1986). Granger causality may have more to do with precedence, or prediction, than with causation in the usual sense. It suggests that while the past can cause/predict the future, the future cannot cause/predict the past. According to Granger, X causes Y if the past values of X can be used to predict Y more accurately than simply using the past values of Y. In other words, if past values of X statistically improve the prediction of Y, then we can conclude that X "Granger-causes" Y.

Islam (2003) also investigated the dynamic interactions between the Kuala Lumpur Stock Exchange (KLSE) composite index, and seven macroeconomic variables (industrial production index, money supply, consumer price index, foreign reserves, credit aggregates and exchange rate). Observing that macroeconomic variables led the Malaysian stock indices, he concluded that Malaysian stock market was informational inefficient. For the leading macroeconomic indicators on the Nairobi Stock Exchange 20-Share Index, the following hypothesis was formulated:

H_0: There are no leading macroeconomic indicators on the trends of the NSE 20-share index.

H_A: There are leading macroeconomic indicators on the trends of the NSE 20-share index.

Where $\mathbf{H_0}$ means the null hypothesis and $\mathbf{H_A}$ means alternative hypothesis.
The p-value approach to Hypothesis testing was used. The p-values returned to the tests were compared to the significance level (α) which was set at 0.01. The statistical decision rule is; if p-value is greater than or equal to the significance level (p-value≥α) the Null Hypothesis is NOT rejected. Else, if the p-value is less than the significance level (p-value≤α), the Null Hypothesis is rejected.

4.4 Leading Macroeconomic Indicators on the Nairobi Stock Exchange 20-Share Index at Different Time Periods

Table 3: Leading macroeconomic indicators on the Nairobi Stock Exchange 20-share index at time period one ($S_{(t)} = M_{(t-1)}$)

		LSE	LTB	LIR	LMS	LREXR	LGDP
LSE	Pearson Correlation	1	.226	-.114	.579(**)	.910(**)	.002
Listwise N=32	S Sig. (1-tailed).	.107	.268	.000	.000	.495	.072

Table 4: Leading macroeconomic indicators on the Nairobi Stock Exchange 20-share index at time period two ($S_{(t)} = M_{(t-2)}$)

		LSE	LTB	LIR	LMS	LREXR	LGDP
LSE	Pearson Correlation	1	.728(**)	-.736(**)	. 812(**)	.819(**)	-.491(**)
Listwise N=30	Sig. (1-tailed)	.	.007	.000	.000	.000	.072

Table 5: Leading macroeconomic indicators on the Nairobi Stock Exchange 20-share index at time period three ($S_{(t)} = M_{(t-3)}$)

			LSE	LTB	LIR	LMS	LREXR	LGDP
	LSE	Pearson Correlation	1	.728(**)	-.736(**)	.812(**)	.819(**)	-.491(**)
A	Listwise N=30	S Sig. (1-tailed)	.	.000	.000	.000	.000	.003

** Correlation is significant at the 0.01 level (1-tailed).

At time period (t-1) One (Table 3), the relationship between the Nairobi Stock Exchange 20 share index and treasury bills, inflation rate, and the gross domestic product at 1% were not significant. The relationship between the NSE 20-Share index with money supply and Inflation rate with correlation coefficient of 0.579 and -0.114 were significant respectively. These two can be considered leading macroeconomic indicator for the NSE 20-share index although for inflation with a very low correlation coefficient it can be considered a weak leading indicator.

At time period (t-2) two (Table 4), the relationship between the Nairobi Stock Exchange Index and the macroeconomic variables were significant at 1%. Since most of the p-values were less than 0.01 i.e. $p<0.01$, the null hypotheses was rejected and therefore we conclude that there are leading macroeconomic indicators on the NSE 20-share index except for the gross domestic product.

At time period (t-3) Three, (see Table 5 above), the relationship between the Nairobi stock Exchange Index and the macroeconomic variables were significant at 1%. The relationship of the NSE 20-share index with the treasury bills, inflation rate, money supply, real exchange rate and the gross domestic product were significant at 0.728, -0.736, 0.812, 0.819 and -0.491 respectively.

Only two macro economic indicators inflation rate and money supply are significant in all the periods (t-1, t-2 and t-3). Inflation is inversely related to the NSE 20-share index. The implication of this especially at t-1 is that anticipation of good or reduced earnings from exports can is the possible reason for this significant correlation with the NSE 20-share index. Money supply from bank loans although it can be factored into the explanation it may not be of significant amounts as there are limited number of persons who can access this loans. For inflation the correlation is low although it can also be explained by the fact that if the agricultural sector's out is reduced that leads to inflation which in turn reduces the possibility of invest in stocks. From the correlation coefficient perspective money supply can be a good leading short run indicator although one needs in addition to anticipate which among the sector one should invest the stocks in.

For the periods t-2 all except gross domestic product can be used as leading indicators their trends being positively correlated with the NSE 20-share index. It is the case that for period t-3 all the Macro economic indicators are leading. However, these two period t-2 and t-3 the respective macroeconomic indicators can be considered as leading indicators for long run investment decisions although the gross domestic product may not be a good leading indicator. To be able to do this it calls for application of forecasting techniques before making the decision to invest in stock and which stocks to invest in.

4.5 Lagging Macroeconomic Indicators on the NSE 20-Share index at Time Period (S(t) =M(t-n)

Lagging indicator is an economic indicator that reacts slowly to economic changes. Lagging indicators demonstrate how well an economy has performed in the past few months, giving economists a chance to review their predictions and make better forecasts. Theoretical reasons for why stock trends might predict economic activity include the traditional valuation model of stock trends and the "wealth effect." The traditional valuation model of stock trends suggests that stock trends reflect expectations about the future economy, and can therefore predict the economy. The "wealth effect" contends that Stock trends lead economic activity by actually causing what happens to the economy.

For the lagging macroeconomic indicators on the Nairobi Stock Exchange 20-share index, the following hypothesis was formulated:

H_0: There are no lagging macroeconomic indicators on the trends of the NSE 20-share index.
H_A: There are lagging macroeconomic indicators on the trends of the NSE 20-share index.

Where **H_0** means the null hypothesis and **h_a** means alternative hypothesis.

The p-Value approach to Hypothesis testing was used. The p-values returned to the tests were compared to the significance level (α) which was set at 0.01. The statistical decision rule is; if p-value

is greater than or equal to the significance level (p-value≥α) the null hypothesis is not rejected. Else, if the p-value is less than the significance level (p-value≤α), the null hypothesis is rejected.

4.6 Lagging Macroeconomic Indicators on the Nairobi Stock Exchange 20-Share Index at Different Time Periods

Table 6: Lagging Macroeconomic Indicators on the Nairobi Stock Exchange 20-Share index at Time Period Two ($S_{(t)} = M_{(t+1)}$)

		LSE	LTB	LIR	LMS	LREXR	LGDP
LSE	Pearson Correlation	1	.244	-.042	.546(**)	.907(**)	.021
Listwise N=32	S Sig. (1-tailed)	.	0.089	.409	.001	.000	.454

Table 7: Lagging macroeconomic indicators on the Nairobi Stock Exchange 20-Share index at Time Period ($S_{(t)} = M_{(t+2)}$)

		LSE	LTB	LIR	LMS	LREXR	LGDP
LSE	Pearson Correlation	1	.101	-.039	.502(**)	.902(**)	-.029
Listwise N=31	S Sig. (1-tailed)	.	.295	.417	.002	.000	.438

Table 8: Lagging macroeconomic indicators on the Nairobi Stock Exchange 20-Share index at Time Period Three ($S_{(t)} = M_{(t+3)}$)

		LSE	LTB	LIR	LMS	LREXR	LGDP
LSE	Pearson Correlation	1	.018	-.025	.466(**)	.913(**)	-.048
	S Sig. (1-tailed)	.	.462	.448	.005	.000	.401

** Correlation is significant at the 0.01 level (1-tailed).

At time period (t+1) One (Table 6), the relationship between the Nairobi Stock Exchange 20 share index and treasury bills, inflation rate, and the gross domestic product at 1% level were not significant. The relationship of the NSE 20-share index with money supply and real exchange rate were significant at 1% significance level with 0.579 and 0.907 respectively. These two macro economic variables were the only ones that were significant in the rest of the period (t+2 and t+3), see Tables 7 and 8. Basically they can be considered that they are lagging variables both in the short run (t=0 and t+1) and in the long run (t+2 and t+3).

4.7 Can the Macroeconomic Indicators be used as Clear predictors of the Stock Trends?

From the results and discussions above the overall question can this lead to a better understanding of trends in NSE 20- share index? Can these results be used to guide the invest decision in the Nairobi Stock exchange? And if this is possible are the macroeconomic variables clear predictors of the stock trends? The results above in conjunction with the evidences in Figure 1 and Figure 2 can be summarized in Figure 4.

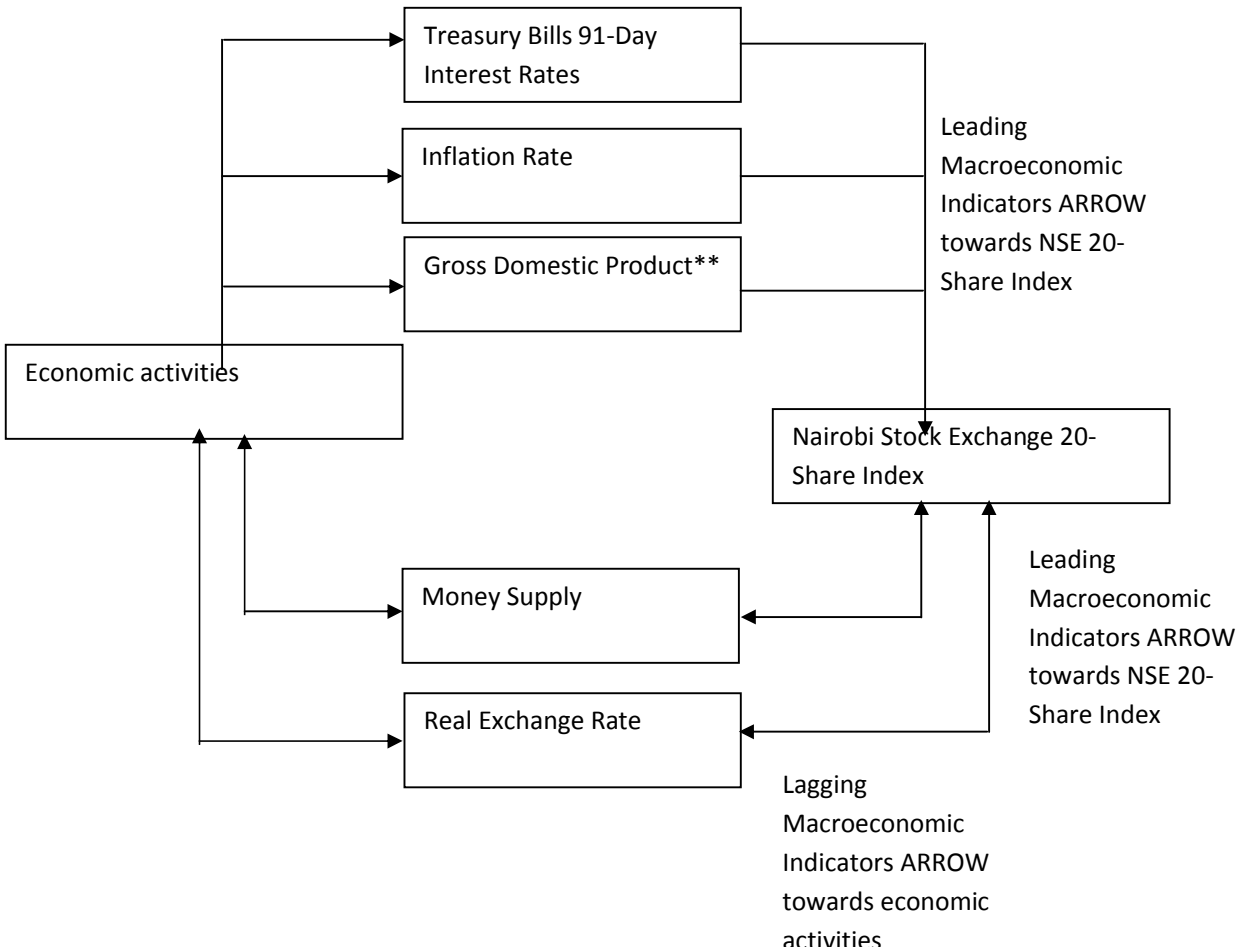


Figure 4: Leading and lagging Macroeconomic indicators of the NSE 20-share index
*** it is a weak leading indicator only significant at t-3*

The results (as summarised in Figure 4 above) indicated that the clear leading indictors were mainly treasury bills and inflation rate. The gross domestic product was equally leading but because it only became significant at period t-3 it is a weak leading indicator. Therefore one can utilise treasury bills which can be considered as a proxy for interest rates and inflation rate to predict the future trends in the NSE 20-share index. Basically interest rates and inflation rates are competitors for funds that would otherwise be invested in stocks. There is a positive correlation between NSE 20-share index and treasury bills (interest rates). This implies when the interest rates are high the private sector would then prefer to borrow from the general public through issuance of cooperate bonds or the floating of shares. This can imply that shares may be looked at as a more logical and cheaper investment opportunity for the general public as it avoids the high money investments that are required for treasury bills. In addition since banks peg their interests on treasury bills interest rates it implies many business people find it difficult to go on with their own activities and probably prefer the stocks instead as it would be cheaper.

For inflation rate since it is negatively correlated to the NSE 20-share index when it is high it implies investors have limited funds to invest and when low they have some excess to invest. The implication of this can be that inflation in Kenya may be more demand push type rather than the monetary based definition of inflation.

Money supply and exchange rate can be considered to be both leading and lagging. They are therefore not good predictors of NSE 20-share index as they are not unidirectional. Exchange rate on the other hand as discussed above may be a proxy of increasing money supply from exports. On this basis it is therefore logical that the two Macroeconomic variables behaved almost the same way in this correlation analysis. The implication for prediction is that the trends in these two macroeconomic variables can be considered as the proxy of what would be happening in the NSE 20-share index on a week to week or month to month basis.

5.0 Conclusions

On the basis of the overall objective whether the macroeconomic variables can predict NSE 20-share index the results indicates that they can be good predictors. It was noted that treasury bills (interest rates) and inflation rates are clear leading indicators for NSE 20-share index. The other macroeconomic were not clear whether they were leading or lagging.

It was also noted from the results that exchange rate and money supply exhibited both leading and lagging tendencies towards the NSE 20-share index. The conclusion here was that they can be argued to be the proxy for the NSE 20-share index trends that is their behavior parallel those of the share index. This may be particularly true for the exchange rate which has very high correlation with the share index in the leading and the lagging correlations. This is also the case with money supply although correlation is lower in comparison to exchange rate.

6.0 Recommendations for Further Research

On the basis of the conclusion and evidences above it is recommended if such as study could be done using data from the other East African countries so as to understand what forces really correlate with the stock indices of the different countries in the context of economic integration.

Money supply and exchange rate seem to be highly correlated with the NSE 20-share index. The ways in which these two macroeconomic indicators relate with stocks share is important to be clarified. They may provide the basis on which day to day trading in the stock exchange and be understood.

References

Bodie, Z. (1976). Common stock as a hedge against inflation", *Journal of Finance*, Vol. **XXXI**(2).

Bulmash, S. B. and Trivoli, G. W. (1991). Time-lagged interactions between Stock trends and selected economic variables, *The Journal of Portfolio Management,* **17**(4), pp 66-67.

Chen, N., Roll, R., and Ross, S.A. (1986). Economic forces and the stock market: Testing the APT and alternative asset pricing theories. Journal of Business.

Chong, C. S. and Goh, K. L. (2003). Linkages of economic activity, Stock trends and monetary policy: the case of Malaysia.

Dilip, K. (1995). International Finance: Cotemporary issues, New York, Oxford University.

Dora, S. and Bancock, M. (1996). Government policy and private investments in developing countries. IMF staff paper, Vol. **31** (2) Fort Worth, Texas.

Fama, E. F. (1970). Multiperiod Consumption Investment decisions. American Economic Review.

Fama, E. F. and Schwert, W. G. (1977). Asset returns and inflation. *Journal of Financial Economics* **5**, pp 115-146.

Fama, E. F. (1981). Stock trends, real Activity, inflation and money. *The American Economic Review* **71**(4), pp 45-565.

Fama, E. F. and Gibbons, M. R. (1982). Inflation, real returns and capital investment. *Journal of Monetary Economics* **9**, pp 297-323.

Fiorito, R. and Kollintzas, T. (1994). Stylized Facts of Business Cycles in the G7 From a Real Business Cycles Perspective. European Economic Review, 38, 2, 1994, pp. 235-69.

Geske, R. and Roll, R. (1983). The fiscal and monetary linkage between stock trends and inflation. *Journal of Finance* **38**(1), pp 1-33.

Granger, C. W. J. (1986). Developments in the study of cointegrated economic variables. *Oxford Bulletin of Economics and Statistics* **48**, pp 213-228.

Hasbrouk, N. (1970). Optimal investment and consumption strategies under risk for a Class of utility functions. Econometrics.

Islam, S. M. N. (2003). Time series financial econometrics of the Thai stock market: a multivariate error correction and valuation model.

Jaffe, J. and Mandelkar, G. (1976). The Fisher effect for risky assets: An empirical investigation. *Journal of Finance* **31**, pp 447-456.

Jordan, J. R. (1995). Security Analysis and Portfolio Management. Prentice- Hall of India.

Kaul, G. (1990). Monetary Regimes and the Relation between Returns and Inflation Expectations, *Journal of Financial and Qualitative Analysis,* Vol. **25**(3).

Kanniainen, V. and Kurikka, V. (1984). "On the Effects of Inflation in the Stock Market, *Journal of Business Finance and Accounting*, Vol **11(**2).

Kibicho, B. (1998). How financial markets affect long –run Growth, A cross-country study. World Bank working papers.

King'ori, E.N. (1995). Stock market seasonalities at the Nairobi Stock Exchange: An Empirical study", Unpublished MBA Project, Universtiy of Nairobi.

Kitchen, R. L. (1995). Finance for the Developing Countries. John Wiley and Sons, West.

Krugman, P. (1995). 'Dutch Tulips and Emerging Markets', Foreign Affairs, Vol.74, No.4.

Kwon, C. (1997). Effect of Macroeconomic Variables on Stock Market Returns in Developing Markets, Multinational Business Revision.

Ma, C. K. and Wenchi, G. (1990). On Exchange Rate Changes and Stock Price Reactions", Journal of Business Finance & Accounting, Vol.**17**(3).

Markowitz, H. M. (1952). Portfolio Selection, *Journal of Finance*, Vol. **7**.

Marshall, D. (1992). Inflation and asset returns in a monetary economy. *Journal of Finance* **47**(4), pp 315-1343.

Maghyereh, T. K. (2002). Dynamic relations between macroeconomic variables and the Japanese stock market: an application of a vector error correction model. *The Journal of Financial Research* **18**(2), pp 223-237.

Maysami, R. C. and Sim, H. H. (2001). Macroeconomic forces and stock trends: a general-to-specific ECM analysis of the Japanese and South Korean markets. *International Quarterly Journal of Finance* **1**(1), pp 83-99.

McDonald, R. and Siegel, D. (1986). The value of waiting to invest. *Quarterly Journal of Economics.*

Miller, M. H. (1972). The Theory of Finance. Holt, Rinehart and Winston, New York.

Mugenda, O. M. and Mugenda, A. G. (2003). Research Methods. Quantitative and Qualitative Approaches. African Centre for Technology Studies (ACTS).

Mukherjee, T. K. and Naka, A.(1995). Dynamic relations between macroeconomic variables and the Japanese stock market: an application of a vector error correction model. *The Journal of Financial Research* **18**(2), pp 223-237.

Nelson, C. R. (1976). Inflation and rates of return on common stocks. *Journal of Finance* **31**(2). pp 471-483.

O'Neil, W. J. (1995). How to make in stocks. A winning system in Good or Bad; Hill Ince New York. Production house Pre-Press Company.

Panetta, F. (2004). The stability of the relation between the stock market and macroeconomic forces. *Economic Notes* **31**(3), pp 417.

Pandey, I. M. (1979). Financial Management Vikas Publishing House.

Pearce, Douglas K. (1983). "Stock trends and Economic News, *Journal of Business,* pp. 49-67.

Reilly, F. K. (1994). Investment Analysis and Portfolio Management, 4th ed., The Dryden Press.

Reilly, F. K. and Brown, C. K. (2006). Investment Analysis and Portfolio Management.

Republic of Kenya (2000). Capital Market Authority Annual Report (2000).

Republic of Kenya (2000). Central Bank of Kenya Annual Report.

Republic of Kenya (2006). Central Bank of Kenya Annual Report.

Republic of Kenya (2006). The Exchange. "The NSE publication", 3rd quarter volume **7.**

Rogalski, R. J. and Vinso, J. D. (1977). "Stocks Returns, Money Supply and the Direction Of Causality", *Journal of Finance*, Vol. **32**(4).

Roll, R. and Ross, S. A. (1986). An empirical investigation of the arbitrage pricing theory.
Journal of Finance.

Sakwa, M. M. (1996). Kenya: Exchange Rate Changes and Horticultural Exports. Unpublished Masters dissertation University of East Anglia.

Stephen, R. and Gary, B. (1991). Investment Behavior. Macmillan Publishers Sussex.

Tobin, J. (1958) Liquidity preference as a behavior toward risk. Review of Economic Studies 25.

World Bank Report (1990). World development report, Oxford University Press, Toronto.

World Bank Report (2001). World development report, Washington, D.C.

Yip, P. (1996). Exchange rate management in Singapore. **In** *Economic Policy Management in Singapore,* ed. Lim Chong Yah, 237-273. Singapore: Addison-Wesley.

Appendices

Appendix I: Raw Project Data

Year	NSE 20-Share Index	Treasury Bill 91- DAY	Inflation Rate	Money Supply	Real Exchange Rate	Gross Domestic Product
1976	213.99	4.37	12.55	42,273.30	18.31	5.10
1977	385.60	1.52	15.86	62,065.50	17.95	2.90
1978	431.64	6.80	16.86	70,589.00	17.40	1.00
1979	356.55	4.60	19.02	81,981.10	17.33	1.20
1980	379.12	6.03	12.85	81,040.10	17.57	1.90
1981	355.85	8.56	12.28	91,822.20	20.27	1.50
1982	350.31	9.62	11.48	106,621.30	22.73	1.61
1983	382.23	15.12	18.74	111,826.70	23.76	2.98
1984	386.55	12.50	10.54	126,210.10	25.78	1.40
1985	420.28	14.14	9.64	134,645.20	26.28	1.90
1986	505.30	11.15	8.40	178,427.50	26.04	1.20
1987	729.49	13.00	6.90	198,330.80	26.52	1.60
1988	856.59	15.00	3.56	214,085.30	28.60	1.40
1989	814.95	14.00	1.41	241,765.00	31.60	1.50
1990	895.76	15.93	-0.70	307,468.30	34.08	1.20
1991	959.97	16.77	-3.66	371,631.40	38.07	2.80
1992	1,246.65	16.96	-1.85	496,459.30	46.22	0.20
1993	2,207.11	39.34	12.55	624,142.20	78.16	0.30
1994	4,559.40	17.90	6.90	81,363.00	54.84	1.80
1995	3,468.88	20.90	6.89	96,489.00	65.94	1.90
1996	3,114.11	21.61	10.80	134,240.00	65.02	0.20
1997	3,115.14	26.36	8.30	147,030.00	72.63	0.60
1998	2,962.06	12.56	2.50	152,895.00	71.83	0.70
1999	2,303.18	20.47	8.00	156,060.00	82.93	0.80
2000	1,913.35	13.47	7.50	157,340.00	88.04	0.60
2001	1,355.10	10.81	1.80	322,320.00	88.60	3.20
2002	1,362.85	8.38	4.10	349,856.00	87.07	0.50
2003	2,737.50	1.41	9.30	395,116.00	91.64	5.20
2004	2,945.58	8.04	16.30	427,798.00	100.39	5.30
2005	3,973.00	8.07	7.60	463,920.00	83.17	5.90
2006	5,646.00	5.73	15.60	653,036.00	88.45	5.20
2007	5,444.80	6.87	12.00	777,596.00	82.13	5.60
2008	3,521.20	8.59	27.70	900,351.00	89.57	1.80

Source: Nairobi Stock Exchange (daily market reports), Kenya National Bureau of Statistics (statistical abstracts) and the Central Bank of Kenya (monthly economic reports).

Appendix II: Transformed Raw Data into Natural Logarithms

Variables	Transformation of Variables	Definitions of Transformations
NAIROBI STOCK EXCHANGE 20-SHARE INDEX (NSE)	LSE	Natural logarithm of the index of market value weighted average of year end closing prices for all the shares listed at the Nairobi Stock Exchange
91-DAY TREASURY BILLS (TB)	LTB	Natural logarithm for the year end yields on the Treasury Bills. This measures the interest rates
INFLATION RATE	LIR	Natural logarithm for the year end Inflation Rates
MONEY SUPPLY	LMS	Natural logarithm for the year end Money Supply
REAL EXCHANGE RATES	LREXR	Natural logarithm for the year end Real Exchange Rates of all major currencies as provided by the Central Bureau of Statistics
GROSS DOMESTIC PRODUCT	LGDP	Natural logarithm for the year end Gross Domestic Product

RETENTION OF STAFF IN PUBLIC UNIVERSITIES

U. Kamau and H. Mberia
Department of Social Sciences and Humanities, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: udikamau@yahoo.com

Abstract
Retention of employees is arguably a widely discussed subject and an important dilemma many organizations and higher institutions of learning might face in the future, if not facing it already. Universities are institutions that develop the kind of expertise and human resource essential to develop the countries policies, governance structures, cultural and socio-economic aspects of development. Globalisation has brought on dynamic markets and competition, and with that it is not hard to picture that universities are likely to focus and should be focusing on long-term strategies and a greater focus on attracting, developing and retaining its employees, particularly the core workers both academic and non academic to guarantee sustainability of programs and personnel. The purpose of this paper is to reveal through review of literature, the identified causes or determinants of staff turnover that may assist university administration reduce staff turnover in public universities. By comparing local and international research findings the paper highlights existing research gaps and findings that can be evaluated and employed to hire, develop and retain a committed workforce in institutions of higher learning. The review focuses on research published in peer reviewed journals from the year 1990 to 2010. The review focused on articles that addressed these concerns and synthesized those with a defensible research design.

1.0 Introduction

University faculties are aging along with the rest of society. Low retirement rates and slow growth in total faculty size limit the number of new hiring opportunities. Institutions are also confronting significant financial difficulties that are the result of substantial reductions in the growth rate of state appropriations or the absolute reductions in annual budgets, declines in endowment, and the escalating costs of employing faculty (Clark and d'Ambrosio, 2005). Clark and d'Ambrosio (2005) continue to add that the importance of these issues varies by type of institution; however, all colleges and universities face a series of common challenges that will shape higher education in the 21st century. In order to maintain high quality faculties in the coming years, universities must develop compensation policies and employment practices that are appropriate for the new economic and demographic environment. A study of turnover by Boxall *et al.,* (2003) in New Zealand confirmed the view that motivation for job change is multidimensional and that no one factor will explain it. A continuous, paramount, and important concern to organizations in the public and private sectors, particularly colleges and universities, is being able to retain qualified and competent employees (Allenand Meyer, 1990; Cohen, 2003; Mowday *et al*., 1982). Many colleges and universities are losing their intellectual capital as faculty migrate to other institutions and consultancy (Gillette, 2002).

According to Tetty (2006) Africa is losing, in significant numbers, a fundamental resource in socio-economic and political development, i.e., its intellectual capital. As the processes of globalization take shape, it is becoming abundantly clear that full, effective, and beneficial participation in the world that is emerging will depend, in no small measure, on the ability of societies to build and take advantage of their human resource capabilities. In the absence of such capabilities, African countries cannot expect to compete at any appreciable level with their counterparts, not only in the industrialized world, but also from other developing areas which have made the investment and developed the relevant capacities. She adds that a well-developed human capacity base is not only an asset that enables countries to promote forward-looking ideas, initiate and guide action, and build on successes; it also makes those countries attractive destinations for investment and intellectual collaboration, both of which, if managed appropriately, will lead to positive returns. A firm higher education base is key for such makeover to take place.

Kenyan universities, particularly public universities as centers of excellence which are responsible for the development of human resources required for national development. Over the last two decades, public universities have been facing a myriad of problems which have affected their ability to motivate and retain their employees (Kipkebut, 2010). Universities, especially public ones, have almost exclusively depended on the government for remunerating their staff. This has led to a situation where staff is not paid as well as their counterparts in the more developed societies. Many professors have therefore decamped to other countries in search of better pay, affecting the teaching needs of Kenyan universities. Demand for better pay has often led to standoffs between the government and the university academic staff union (UASU) (Chacha, 2004).

Retention in this article an awning term that is used to describe the efforts university management may utilize to reduce turnover of both academic and non-academic personnel. In promoting retention of staff, it is essential that the effectiveness of these processes leaves no gaps. However, what evidence do we have that the processes we are advocating are effective? An important observation is that universities must engage in more institutional research. Pooling of data from similar universities is necessary if we are to understand the complexities of employment and compensation policies (Baer, Freund, Kuhn, Schulenburger and Spies, in press).

This paper will attempt to shed light by revealing through review of literature, the identified causes or determinants of staff turnover that may assist university administration reduce staff turnover in

public universities. By comparing local and international research findings the paper highlights existing research gaps and findings that can be evaluated and employed to hire, develop and retain a committed workforce in institutions of higher learning. The review focuses on research published in peer reviewed journals from the year 1990 to 2010. The review focused on articles that addressed these concerns and synthesized those with a defensible research design.

2.0 Materials and Methods

The aim of the review was to identify and analyze the main factors affecting retention of staff in public universities. Studies published between 1990 and 2010 in English were searched using the electronic databases: Emerald, Springer, JSTOR, Wiley inter-science, Project MUSE. Key words used in the search are shown in table 1. Of the 3986 research papers initially identified using the search criteria, 3576 proved irrelevant when titles were examined and 130 were duplicates. The abstracts of these 280 papers were examined, 84 had relevant content the full text was not available to 5 of these. Of the 79 accessed 66 were excluded after reading the full text resulting in 13 being examined in full. A systematic review was carried out and both quantitative and qualitative studies were included.

Table 1: Search key words

Staff retention/	or employee retention/	or worker retention/	or knowledge worker retention
Staff turnover/	or employee turnover/	or worker turnover/	or knowledge worker turnover
Developing countries/	or middle income countries/	or low income countries/	or poor countries
Public universities/	or higher education/	or higher learning institutions/	or campuses

There is no single agreed framework for synthesizing the extensive range of evidence available. Indeed, integrating different types of data within one review is one of the key challenges facing systematic reviewers (Thomas *et al*., 2004). Relationships between the different areas were thus identified and grouped into the sections discussed below.

3.0 Results and Discussions

This review has evaluated a limited number of studies published in English in peer-reviewed journals during 1990–2006. Book chapters and grey literature are not included because of space constraints. Although the review has identified several important factors, they should be seen as context - or country-specific. The choice to exclude non-English language studies and the grey literature was made for practical reasons based on the increased time, expense and complexity of translating and synthesizing these studies. However, it is worth noting that much research in developing countries may not be published in peer-reviewed journals, but might be available as grey literature in local dialects.

4.0 Results

The 13 studies identified factors affecting staff sustainability which were categorized into 10 themes (see table 2): career, job context, empowerment, group influence, expectancy, leadership, individualism and collectivism, masculinity and femininity, balance between the private and personal life, and rewards.

Table 2: Summary of significant factors in the retention of staff

Major factors	*Significant factors*	*Total number of studies*	*References*
Career	Job content	1	Naris & Ukpere (2010)
	Job satisfaction	2	Vicki & Barbara (2006), Manger & Eikeland (1990)
	Role conflict	1	Daly and Dee (2006)
Masculinity and femininity	Having more women	1	Tolbert et al (1995
	Female incumbents	1	Pfeffer & Davis-Blake (1992)
Expectancy	Lack of commitment	1	Mallam (1994)
	Morale	1	Johnsrud & Rosser (2002)
	Perceptions of work life	1	Johnsrud & Rosser (2002)
	Review and promotion process	1	Jayakumar et al (2009)
	Satisfaction with job security	1	Ying & Volkwein (2004)
	Perceived plentiful job opportunities	1	Daly& Dee (2006)
	Work less intrinsically satisfying	1	Manger & Eikeland (1990)
Group influence	Collegial relations	1	Manger & Eikeland 1990)
	Minority status	1	Ying & Volkwein (2004) Jayakumar
	Negative racial climate	1	et al (2009)
Empowerment	Autonomy and independence	2	Jayakumar et al (2009), Daly & Dee (2006)
	Growth opportunities	3	Mallam (1994) ,Victoria (2008), Naris & Ukpere (2010)
Leadership	Communication openness	1	Daly & Dee (2006)
	Distributive justice	1	Daly & Dee (2006)
	Position level of supervisors	1	Ashley (2006)
	Supervisory skills	2	Victoria (2008), Ashley (2006)
Individualism and collectivism	Doctoral degree	1	Ying & Volkwein (2004) Jayakumar
	Colleague research value	1	et al (2009)
Private and personal life.	Proximity of family	1	Daly & Dee (2006)
Rewards	External extrinsic reward	1	Ying & Volkwein (2004)
	Pay	3	Ying & Volkwein (2004), Mallam (1994), Naris and Ukpere (2010)
	Position in the salary structure	1	Pfeffer & Davis-Blake (1992) Ying & Volkwein (2004)
	Satisfaction with compensation	1	

4.1 Career

Career factors include the job content, job satisfaction and role conflict. One study found that Job content was a good predictor of staff turnover. The indications are that administrative staff felt that they were not given opportunities to apply their knowledge and skills, which they gained at

development programs, to the job (Naris and Ukpere, 2010). In contrast Vicki & Barbara (2006) found that work-life had a significant and positive impact on satisfaction but no direct effect on intent to leave.

Two studies indicated that job satisfaction was a good predictor of staff turnover. In both studies job satisfaction had a significant and negative impact on intent to leave (Vicki & Barbara, 2006; Manger and Eikeland, 1990).

One study associated Role conflict with intentions for turnover. Role conflict revealed a detrimental effect on job satisfaction and organizational commitment, which in turn diminished intent to stay (Daly and Dee, 2006).

4.2 Job Context

Job context factors include the employee's academic rank, their being a full professor, length of tenure in the organization, type of tenure with the organization and how flexible work/life policies are.

A study on tenured and non-tenured faculty reveals that academic rank is a determinant to turnover intentions. For both groups of faculty, seniority has the strongest direct effect on departure intention. Senior faculty, those who are advanced in age, career age, and who have served their institutions for a longer period of time, are less likely to leave (Ying & Volkwein, 2004). However academic rank has different impacts on tenured vs. non-tenured faculty. For the tenured group, academic rank increases faculty's job security and indirectly reduces their departure intention. For the non-tenured group, although it increases one's satisfaction with job security, more important, it directly strengthens one's departure intention. With college administrators, tenure in the job was negatively related to turnover; however organizational size and heterogeneity in the tenure distribution had significant positive effects on turnover (Pfeffer and Davis-Blake, 1992).

Being a full professor was also significantly associated with negative intentions to leave. Findings reveal that at the individual-level (within groups), being a full professor had a negative and significant impact on intent to leave. Being an instructor on the other hand had no effect intent (Johnsrud and Rosser, 2002).

Length of tenure as a job context factor was also an indicator of retention. It was found to have a significant and negative impact on their work life and intent to leave (Vicki and Barbara, 2006).

Vicki and Barbara (2006) also identified type of tenure as a factor influencing staff turnover. They report that being a full-time faculty member had a significant and negative impact on intention to leave.

One study did reveal that flexible work/life policies have a significant relationship with intentions to leave. The study found that turnover among women administrators was influenced by an inability to negotiate a flexible work schedule (Victoria, 2008).

4.3 Empowerment

Five studies found empowerment factors as indicators of intentions for turnover. The empowerment factors include autonomy and independence, presence of growth opportunities and the lack of career opportunities. One research indicates that a positive factor in retention can be explained by the autonomy and independence an individual enjoys. This factor demonstrated a positive correlation with intent to stay (Jayakumar *et al.*, 2009; Daly and Dee, 2006).

Growth opportunities were moreover identified as significant factors affecting job turnover. A number of studies report that the availability of promotion opportunities appear to be perceived as an influential factor among faculty members to voluntarily relinquish their jobs or quit their institutions (Mallam, 1994; Victoria, 2008; Naris and Ukpere, 2010).

4.4 Group Influence

Group influence factors include collegial relations between faculty members, the minority status particular group may face and a perceived negative racial climate. One study identifies collegial relations as a significant factor in retention of staff. The study results show that collegial relations had the largest contribution on the dependent variable intention to leave the university (Manger and Eikeland, 1990).

Two of studies concurred that minority status is a significant variable in the prediction of intentions for turnover. They report that minority faculty, tenured or non-tenured, are more likely to leave. (Yingand Volkwein, 2004; Pfefferand Davis-Blake, 1992).

A negative racial climate is also identified as a factor that could determine turnover intentions. For the minority groups cross tabulations revealed that more faculty who perceived a hostile racial climate indicated a desire to leave compared to those who perceived a moderate/mild or a benign racial climate (Jayakumar *et al*., 2009).

4.5 Expectancy

Expectancy factors included the lack of commitment, issues regarding morale with work, the perceptions of work life by employees, the review and promotion process, satisfaction with job security, perceived plentiful job opportunities and work being less intrinsically satisfying.
Lack of commitment is a factor identified as predicting intentions for turnover. Male faculty members reported that their former colleagues were more likely to leave voluntarily due to lack of commitment to their institutions (Mallam, 1994).

Faculty morale also had a significant direct and negative effect on intent to leave (Johnsrud and Rosser, 2002). Johnsrud and Rosser (2002) reveal that the relationship between morale and intent to leave is considerable at the individual level. Both perceptions of work life and morale have significant direct impact on the intent to leave, with perceptions of work life having a positive, modest impact (and substantive negative indirect effect) and morale having a negative and substantial effect.

Review and promotion process is identified as a factor that additionally determines staff turnover intentions. Jayakumar *et al*., (2009) discuss in their findings that stress from the promotion process consistently has a negative association with retention. Satisfaction with job security determines intention for retention. Faculty members who are satisfied with their job security on campus are more likely to stay (Ying and Volkwein, 2004).

One study by Daly and Dee (2006) as well shows that perceived plentiful job opportunities increases the turnover intentions. Their research documents those respondents who perceived plentiful job opportunities reported lower levels of intent to stay. A different study traces the fact that workers who find work less intrinsically satisfying can be used as a predictor of turnover. The data from the study showed that staff having the intention to leave the university find their work less intrinsically satisfying as compared to staff choosing to stay (Manger and Eikeland, 1990).

4.6 Leadership

Leadership factors include organizational communication openness, the perceived distributive justice, the position level of supervisors and the supervisory skills of the employee's supervisors.

The communication openness in an organisation demonstrated a positive correlation with intent to stay. Daly and Dee (2006) indicate that higher levels of open communication were associated with higher levels of satisfaction and commitment, which in turn yielded higher levels of intent to stay. They continue to add that distributive justice had a positive indirect effect through organizational commitment. Higher levels of distributive justice were associated with higher levels of commitment, which in turn strengthened intent to stay.

Ashley (2006) points out an additional factor, the position level of supervisors was found to be correlated to supervisees' intention to turnover. This is in the findings coupled to lack of experience of middle level and entry level supervisors and the association with new professionals' intention to turn over.

Supervisory skills are also identified as an auxiliary factor determining departure intentions. The results indicate that because of the immediate supervisor most left, and the most common response to the interview question, ''what might have prevented the departure?'' was ''better supervisor treatment'' (Victoria 2008; Ashley 2006).

4.7 Individualism and Collectivism

Individualism and collectivism factors include having a doctoral degree and having one's research valued by colleagues in the department. The faculty members who have a doctoral degree, because of their lower satisfaction with compensation, are more likely to leave (Ying and Volkwein, 2004). Having one's research valued by colleagues in the department is also recognized a having a strong association with retention (Jayakumar *et al.*, 2009).

4.8 Masculinity and Femininity

Masculinity and femininity factors include the proportion of women in the organization and the effect of number of women in the institution on men. Pfeffer and Davis-Blake (1992) indicate that female incumbents were marginally more likely to leave their positions. Tolbert et al (1995) interestingly found that having more women decreases the likelihood of turnover among male faculty.

4.9 Balance between the Private and Personal Life

Faculty with one or more immediate family members living in the area had higher levels of intent to stay than faculty with no immediate family living within 50 miles (Daly and Dee, 2006).

4.10 Rewards

Employees whose salaries were high compared to the salaries of persons performing the same jobs in other institutions were less likely to leave their positions (Pfeffer and Davis-Blake, 1992).

Pfeffer and Davis-Blake (1992), however, demonstrate that internal salary distributions significantly affect turnover, even when external comparisons are controlled, the low earners in a salary distribution appear to react negatively to high salary dispersion, regardless of whether their lower salaries are equitably related to differences in skill, experience, or the nature of their positions. Conversely the same study finds that if workers conclude that good performance is rewarded, they may be likely to remain with the organization.

External extrinsic reward is also identified as a predictor of turnover. The faculty members that regard external extrinsic rewards as highly important are less likely to leave (Ying and Volkwein, 2004).

With regard to pay as a predictor of turnover, faculty members under 25 years regarded pay as a factor influencing voluntary turnover as opposed to their colleagues within the age ranges (a) 31 to 35; (b) 36 to 40; and (c) 46 or above (Mallam, 1994), in addition, the level of education with respect to pay, faculty members with Bachelor's degrees perceived their colleagues to be more inclined to leave voluntarily than faculty members with Master's degrees. However, Naris and Ukpere (2010) find that the notch increase, which is the financial reward that they received after obtaining their qualification, was not sufficient and was reason enough for ex-employees interviewed to leave the institution.

Satisfaction with compensation is the second strongest predictor of tenured faculty's departure intention in a study by Ying and Volkwein (2004), but its influence on non-tenured faculty is much weaker. They find those tenured faculties who feel they are underpaid are more likely to consider another position.

5.0 Conclusion

This review of turnover literature identifies an array of factors that have been shown to be consistently linked to turnover. These however do not include percentage of women in organisations and perceived racial climate, their role is still somewhat inconclusive and should be able, with further analysis, to generate new information that could help us in our goals towards attaining gender mainstreaming and racial/ethnic tolerance. Echoing Clark and d'Ambrosio (2005) the importance of these issues varies by type of institution; In order to maintain high quality faculties in the coming years, universities must develop compensation policies and employment practices that are appropriate for the new economic and demographic environment. This would necessitate the need for additional research in local Kenyan universities comparing the identified causes with research in these international findings and as a result deliver sustainable methods of retaining staff. This additional research on turnover in the public universities could include an examination of turnover data to establish whether turnover is uniformly high across the higher education sector or whether there are differences. The collation of qualitative data through employee surveys at the university level may be useful for identifying sources of dissatisfaction, intentions to leave, and any underlying causes of turnover.

References

Allen, N. J. and Meyer, J. P. (1990). The measurement and antecedents of affective, continuance, and normative commitment to the organization. *Journal of Occupational and Organizational Psychology*, **63**(1), pp 18-38.

Baer, M., Freund, D., Kuhn, C., Shulenburger, D. and Spies, R. (in press). *Recruitment, retention, and retirement: Institutional research and the need for data*. In R. Clark and J. Ma (Eds.), Recruitment, retention, and retirement in higher education: Building and managing the faculty of the future. Northampton, MA: Edward Elgar Publishing.

Boxall P., Macky K. and Rasmussen E. (2003). Labour turnover and retention in New Zealand; the causes and consequences of leaving and staying with employers, *Asia Pacific Journal of Human Resources*, vol.**41**(2), pp 196-214.

C Nyaigotti-Chacha (2004). Reforming Higher Education in Kenya Challenges, Lessons and Opportunities. The Inter-University Council for East Africa.

Cheryl J. Daly and Jay R. Dee. (2006). Greener Pastures Faculty Turnover Intent in Urban Public Universities. *The Journal of Higher Education*, Vol. **77**(5) (Sep. - Oct., 2006), pp. 776-803.

Cohen, A. (2003). Multiple Commitments in the Workplace: An Integrative Approach. New Jersey: Lawrence Erlbaum Associates, Publishers. Commissioned by the World Bank DOI: 10.1353/csd.2006.0053.

Gillette, B. (2002). State budget problems, higher education funding cuts spark exodus, *Mississippi Business Journal*, **24**(42), pp 15.

Jeffrey Pfeffer and Alison Davis-Blake. (1992). Salary Dispersion, Location in the Salary Distribution, and Turnover among College Administrators. *Industrial and Labor Relations Review*, Vol. **45**(4) pp. 753-763.

Johnsrud, Linda K. and Rosser, Vicki J. (2002). Faculty Members' Morale and Their Intention to Leave: A Multilevel Explanation. *The Journal of Higher Education*, Volume **73**(4), July/August, pp. 518-542 (Article).

Mowday, R. T., Porter, L. W. and Steers, R. M. (1982). Employee-organizational linkages. New York: Academic Press.

N. Sylvia Naris and I. Wilfred U. (2010). Developing a retention strategy for qualified staff at the Polytechnic of Namibia. *African Journal of Business Management* Vol. **4**(6), pp. 1078-1084, June 2010.

Pamela S. Tolbert, Tal Simons, Alice Andrews, Jaehoon Rhee, (1995). The Effects of Gender Composition in Academic Departments on Faculty Turnover. *Industrial and Labor Relations Review*, Vol. **48**(3) pp. 562-579.

Provost L. N. (2008). UNC Tomorrow Phase II Campus Response Faculty and Staff Recruitment and Retention. NC State University.

Robert L. Clark and Madeleine B. d'Ambrosio, (2005). Recruitment, Retention, and Retirement: Compensation and Employment Policies for Higher Education. Taylor and Francis Inc.

Terje Manger and Ole-Johan Eikeland, (1990). Factors Predicting Staff's Intentions to Leave the University. *Higher Education journal*, Vol. **19**(3), pp. 281-291.

Thomas J., Harden A., Oakley A., Oliver S., Sutcliffe, K., Rees R., Brunton G. & Kavanagh J. (2004) Integrating qualitative research with trials in systematic reviews. *British Medical Journal* **328**(7446),pp 1010–1012.

Tull, Ashley. (2006). Synergistic Supervision, Job Satisfaction, and Intention to Turnover of New Professionals in Student Affairs*. Journal of College Student Development*, Volume **47**(4), pp. 465-480 (Article). Published by The Johns Hopkins University Press.

Ugbo M.(1994). A National Research Study on Factors Influencing Faculty Turnover at Selected Nigerian Colleges of Technology/Polytechnics. Plateau State Polytechnic, Jos-Campus, Nigeria. Higher Education 27: 229-238. Kluwer Academic Publishers. Printed in the Netherlands.

Uma M. J., Tyrone C. H., and Walter R. A. (2009). Racial Privilege in the Professoriate: An Exploration of Campus Climate, Retention, and Satisfaction. *The Journal of Higher Education*, Volume 80, Number 5, September/October 2009, pp. 538-563 (Article) Published by The Ohio State University Press. *DOI: 10.1353/jhe.0.0063.*

Vicki J. Rosser and BarbaraK (2006). Townsend Determining Public 2-Year College Faculty's Intent to Leave: An Empirical Model. *The Journal of Higher Education*, Vol. **77**(1), Ohio State University.

Victoria H. Jo, (2008) Voluntary turnover and women administrators in higher education. *Springer Science + Business journal* Media B.V. Published online: 10 January 2008.

Wisdom J. Tettey (2006). Staff retention in african universities: Elements of a sustainable strategy. Faculty of communication and culture, University of Calgary, Calgary, Alberta, Canada.

Ying Zhou and James F. V. (2004). Examining the Influences on Faculty Departure Intentions: A Comparison of Tenured Versus Nontenured Faculty at Research Universities Using NSOPF-99. *Research in Higher Education*, Vol. **45**(2).

THE EFFECT OF MARKET POSITIONING ON ORGANIZATIONAL PERFORMANCE IN THE AIRLINES INDUSTRY IN KENYA; CASE OF KENYA AIRWAYS

S. O. Mokaya[1], P. Kanyagia[2] and G. M. M'Nchebere[3]
[1]Jomo Kenyatta University of Agriculture and Technology
[2]Kenya Airways
[3]Moi University
E-mail: skomokaya@yahoo.com

Abstract
Market positioning has long been recognized as a vital tool to confront competitive pressures and improve organizational performance. Firms which position themselves within a particular market place relative to competitors, earn higher rates of return. Competition and profitability pressures mean that firms must be responsive to the market conditions. The study sought to determine the effects of market positioning strategies on organizational performance in the airlines industry in Kenya using Kenya Airways (KQ) as a case. The study covered 215 respondents drawn from a population of 1230 (staff and customers). Questionnaire was used to collect data. Content analysis, descriptive and Pearson's Product Moment of Correlation were used to analyze data. The results revealed that variations in organizational performance are explained by pricing strategies with a confidence level of 95%. The results indicated a P-value of less than 0.005 against all the study variables. Pricing strategies had a significant effect on cost strategies, perceived service quality, differentiated benefits, innovation and organizational performance. The study revealed a positive correlation between pricing strategies and perceived service quality with a correlation coefficient of 0.574; an average and positive correlation between pricing strategies and innovation with a correlation coefficient of 0.464. There also existed a positive correlation between pricing strategies and differentiated benefits with a correlation coefficient of 0.650. Moreover, the correlation efficient between pricing strategies and performance was also positive, meaning that as a firm charges fair prices, compared to its competitors, performance is improved as supported by Kimes and Wirtz (2002). Pricing strategies had a coefficient value of 0.170 against organizational performance. The study concluded that positioning is firmly placed within the general segmentation-targeting-positioning framework and plays a pivotal role in marketing strategy. Market positioning strategies have yielded to improved performance. The study recommends that KQ and indeed other airlines should continue positioning themselves favorably within the global market to enable them earn high profits. They should plan the product mix for a combination of elements such as physical product, product services, brand and package desired by the target consumers. Further, they should continue their focus on high quality service to customers and markets in order to build customer royalty.

Key words: Market positioning, marketing strategy, organizational performance, pricing strategies, segmentation-targeting-positioning, product mix

1.0 Introduction

Marketing as an organizational philosophy requires that an understanding of customer needs should precede and inform the development and marketing of products and services as opined by (Kotler, 1997). *Marketing as a strategy* defines how an organization is to compete and survive in the marketplace. Organizational performance is what business executives and owners are usually frustrated about, because even though employees are hard-working, and are busy doing their tasks, their companies are unable to achieve the planned results (Smith, 1995). Competitive advantage is achieved by a combination of unique resources and a high level of competence (Das and Teng 2000), and marketing executives must plan the product mix that will result in a combination of elements that make up the product (physical product, product services, brand and package desired by the target consumers).

A market position reflects how consumers perceive the product's or organization's performance on specific attributes relative to that of the competitors (Kotler, 1994). Positioning is a competitive marketing tool that goes beyond image-making. It is an attempt to distinguish an organization from its competitors, in order to be the most preferred firm for a certain market segment. It is establishing and maintaining a distinctive place and image in the market for product offerings so that the target market understands and appreciates what the organization stands for in relation to its competitors (Ries and Trout, 1986). A firm that positions itself favorably within a particular marketplace, relative to competitors, can earn high profits irrespective of average profitability within the market. Competition and profitability pressures mean that firms must be increasingly responsive to market considerations in terms of their positions.

Successful consumer marketing begins with consumers who need the product and have the resources to buy it. However, these consumers do not buy just a product; they buy a total bundle of values (market offering). The market offering is composed of a mix of elements such as a product, product services, transaction services, brand, package, price, credit terms, price discounts, advertising, personal sales assistance, store or business location availability, inventory assortment and transportation services. Mixing and matching these various elements of the market offering into an appropriate integrated and unified whole becomes the primary focus in developing a successful competitive position in the marketplace today.

1.1 Statement of the Problem

Positioning is a powerful tool that allows a firm to create an image. In recent years the airline industry has witnessed increased emphasis on the cultivation of a culture which fosters the effective implementation of marketing programmes. This growing attention stems from the belief that sound marketing practices provide an important source of competitive advantage in the service sector which is characterized by high levels of interaction between firms and their customers. A strong marketing culture leads to customer retention, which in turn, yields higher profitability (Ries and Trout, 2000).

Kenya Airways market dominance and profitability has been declining over the recent years as indicated in their financial results. In view of profitability achieved over a period of 2006-2007 and 2007-2008, the firm's net profit was down 5.6%, while the revenue for the same period was up 19.6%. For the period between 2007 – 2008 and 2008 – 2009, the net profit was down again by 182.9% while the revenue for the same period was down by 35.4%. For an airline to become profitable it must put in place strategies that position itself in market dominance and improve the firm's overall performance. Marketing positioning has been recognized as a vital tool to confront the competitive pressure in the airline market environment and also as a tool of improving the performance of these firms. Though the marketing positioning concept and its effect on firm performance has received considerable attention, there is limited empirical literature on its practice

and effects on firm performance in the Kenyan context. The study sought to determine the effects of marketing positioning strategies on the performance of airline industry with specific reference to Kenya airways.

1.2 The Purpose

The purpose of the study was to determine the effects of marketing positioning strategies on the organization performance of Kenya Airways Limited. Specifically the study sought to establish the effect of pricing strategies on the performance Kenya Airways Limited, perceived service quality on the performance of Kenya Airways, innovation strategies on the performance of Kenya Airways, differentiated benefits on the performance the Kenya Airways, cost strategies on the on the performance of the Kenya Airways.

2.0 Methodology

The study adopted an exploratory design covering a stratified sample of 215 respondents drawn from a population of 1230 (staff and customers). A semi-structured survey questionnaire was used to collect data which was analyzed using descriptive and inferential statistics. In particular, Pearson Product Moment Correlation was used to establish the relationship between the variables under study. However, before detailed analysis, data was categorized into themes guided by the objectives of the study. Content analysis was used to analyze the respondents' views on the market positioning strategies adopted by Kenya Airways. The organized data was interpreted on account of concurrence, mean and standard deviation using SPSS computer software.

3.0 Results and Analysis

The study sought to analyze the market domain of Kenya Airways as understood by the respondents from a market positioning view in relation to organizational performance. A combined 89% of the respondents interjected that positioning is firmly placed within the general segmentation-targeting-positioning framework with the remaining percentage not sure of the positioning of the airline within the framework. Almost all the respondents felt that marketing positioning is the backbone of Kenya Airways' business plan, with 98% feeling that it was used to a very great extent and 2% to a great extent. Although the underlying concepts of market positioning are similar in consumer and business marketing and that differential approaches are needed during implementation, Kenya Airways provides a combination of features perceived to be desirable by the target market.

3.1 Pricing Strategies

The value of any pricing strategy is questionable if it is not congruent with the overall strategy of the firm. Pricing strategies, which do not reflect organizational goals, can detrimentally affect performance outcomes. The consequences of pricing strategies have important managerial and public policy implications. Majority of the respondents were of the opinion (strongly agreed or agreed) that pricing has a strong effects on organizational performance.

With a P-value of less than 0.005 against all the study variables, the Pearson Correlation analysis indicated that pricing strategies had a significant effect on these study variables namely the cost strategies, perceived service quality, differentiated benefits, innovation and organizational performance. There existed a fairly strong and positive correlation between Pricing Strategies and Perceived Service Quality with a correlation coefficient of 0.574; an average and positive correlation between Pricing Strategies and Innovation with a correlation coefficient of 0.464. There also existed a strong and positive correlation between Pricing Strategies and Differentiated Benefits with a correlation coefficient of 0.650. Moreover, the correlation efficient between pricing strategies and performance of Kenya

Airways was also positive meaning that as a firm charges fair prices as compared to its competitors, organizational performance is enhanced (Kimes and Wirtz, 2002).

Pricing strategies had a coefficient value of 0.170 against organizational performance when the marketing positioning elements (independent variables) were regressed against the dependent variable (organizational performance). The results revealed that 17.4% of the variations in organizational performance are explained by pricing strategies with a confidence level of 95%. It was found that the effect of pricing strategies, though significant, have low explanatory power on corporate performance. This means that hypothesis one did not accurately predict the outcome of the study, leading to rejecting the null hypothesis.

3.2 Perceived Service Quality

Service quality is the discrepancy between what customers expect and what customers get, and it is evaluated through five dimensions, tangibles, reliability, responsiveness, assurance, and empathy. Accordingly, organizational competitiveness is possible to support service firms to provide high service quality to customers and markets in order to encourage a competitive advantage and receive a superior performance. The study thus sought to find out how the five dimensions are adopted to enhance organizational performance within the study scope. All the dimensions of service quality show a high adaptability level (90%), indicating the effort and commitment by Kenya Airways to offering its customers the best of service.

There existed a fairly strong and positive correlation between Perceived Service Quality and Pricing Strategies with a correlation coefficient of 0.574. There existed a less than average and positive correlation between Perceived Service Quality and Innovation with a correlation coefficient of 0.0.241 and an equally below average correlation between perceived service quality and Differentiated Benefits with a correlation coefficient of 0.289. There was, however, a low key negative correlation between perceived service quality and cost strategies with a coefficient of -0.139.

The correlation efficient between perceived service quality and organizational performance of Kenya Airways was also positive meaning that the more innovative a firm becomes, the more organizational performance was enhanced. The coefficient of determination between perceived service quality and organizational performance was 0.167 which was a strong positive of regression. The results indicated that 24.8% of the variations in organizational performance are explained by perceived service quality, with a confidence level of 95%. In view of this one, the effect of perceived service quality, though significant, has low explanatory power on organizational performance which implies that hypothesis two did not accurately predict the outcome of the study, leading to rejecting the null hypothesis.

Innovation is closely related to organizational performance, and according to Thompson (1996) innovation as the generation, acceptance, and implementation of new ideas, processes, products, or services. Thus, an innovative organization is taken to be a learning organization and at the same time a performing one. This study sought to establish the respondents' views on the relationships that exist between innovation, the learning organization, and organizational performance. According to the results, all the variables under the innovation concept had a high support, with the lowest being 75%. It was established that organizational performance is associated with the development of new knowledge, which is crucial for firm innovation capability and firm performance and that an innovative organization closely monitors the competitors' actions in the market and that an

organization committed to learning is likely to have greater innovation capability than competitors.

3.3 Differentiated Benefits

Differentiation is a marketing process that showcases the differences between products. It looks to make a product more attractive by contrasting its unique qualities with other competing products. Successful product differentiation creates a competitive advantage for the seller and thus enhances firm performance as customers view these products as unique or superior. Product differentiation can be achieved in many ways. It may be as simple as packaging the goods in a creative way, or as elaborate as incorporating new functional features. Sometimes differentiation does not involve changing the product at all, but creating a new advertising campaign or other sales promotions instead (Galbraith, 1997). The results in Table 6 showcase a scenario where most of the strategies have been adopted to either a moderate extent or to a little extent, meaning a lot of effort has to be put into place to ensure that these strategies are adapted in order to have more unique, distinguished products at Kenya Airways. However, the scatter was quite high peaking at 1.30 showing a high degree of indecisiveness among the respondents. This high scatter can also be explained by the big range of 4 between the minimum observation and the maximum for most of the responses as shown in Table 1.

Table 1: Extent of Adoption of Differentiated Benefits Strategies by KQ

Strategy	Count	Min	Max	Mean	S.D.
Packaging of goods in a creative way	89	1	4	3.13	0.87
Incorporating new functional features	92	2	5	3.65	1.30
Creating a new advertising campaign or other sales promotions	92	1	5	4.97	1.12

Source: Research Data (2010).

The study established that product differentiation involves differentiating a product from competitors' products as well as one's own product offerings in order to enhance firm performance. Kenya Airways adopts the product differentiation strategy of packaging of goods in a creative way and incorporating new functional features in a bid to improve its performance. The study also established that for the company to achieve better performance, the marketing executives must plan the product mix that will result in a combination of elements such as physical product, product services, brand and package desired by the target consumers and that product differentiation at Kenya Airways is done in order to demonstrate the unique aspects of their product and create a sense of value which guarantees better performance.

3.4 Costing and Promotion

Costing strategy involves the firm winning market share by appealing to cost-conscious or price-sensitive customers. This is achieved by having the lowest prices in the target market segment, or at least the lowest price to value ratio (price compared to what customers receive). To succeed at offering the lowest price while still achieving profitability and a high return on investment, the firm must be able to operate at a lower cost than its rivals. The study revealed that cost strategies are very important in enhancing the performance of Kenya Airways as they inform and educate the

market, increase sales, maintain and improve market share, create and improve brand recognition and create a competitive advantage relative to competitor's products and market position.

The study revealed that promotional activities were very important in increasing sales as supported by all the respondents (Table 2). In improving and maintaining market share, promotional activities are equally very important as indicated by 98% of the respondents. However, in creating a competitive advantage, relative to competitor's products or market position, respondents had mixed reactions, with the majority (42%) rating promotional activities' role as very important, 10% as important, 34% as somehow important and 14% as not important.

Table 2: Role of promotional activities in organizational performance

Role	Count	1		2		3		4		5	
		C	%	C	%	C	%	C	%	C	%
Increase sales	92	92	100	0	0	0	0	0	0	0	0
Maintain or improve market share	91	89	98	2	0	0	0	0	0	0	0
Create or improve brand recognition	92	79	86	10	11	3	3	0	0	0	0
Create a favorable climate for future sales	89	88	99	1	1	0	0	0	0	0	0
Inform and educate the market	92	89	97	3	3	0	0	0	0	0	0
Create a competitive advantage, relative to competitor's products or market position	91	38	42	9	10	0	0	31	34	13	14

Source: Research Data (2010).

The study sought to assess key performance indicators within the context of Kenya Airways. With the means ranging between 0.59 and 1.99, respondents were in agreement that the aspects presented played a big part in improving organizational performance. This finding is in consonance with Dunphy, Turner & Crawford (1996) who studied the strategy that helps to explain why certain organizations achieve superior organizational performance; while Michael Porter (1980) explains the success of an organization's competitive strategy dependence upon a set of strategic choices that positions the organization successfully within a particular industry or environmental niche.

3.5 Analysis of the effect of Market Positioning Variables on Organizational Performance

This was done using regression analysis in respect of each research objective and hypothesis. Table 3 shows the results from the simple regression analysis carried out.

Table 3: Regression analysis of market positioning variables

Model	R^2	DF	F	P-Value
H_1	0.174	47	9.714	0.003
H_2	0.248	47	15.204	0.000
H_3	0.343	37	18.789	0.000
H_4	0.118	48	6.303	0.016
H_5	0.391	18	10.933	0.004

Source: Research Data (2010).

HI: There is no significant relationship between pricing strategies and performance
The results reveal that 17.4% of the variations in organizational performance are explained by pricing strategies, with a confidence level of 99%; nearly 82.6% is explained by other factors. It was found that the effect of pricing strategies, though significant, have low explanatory power on corporate performance. This means that hypothesis one did not accurately predict the outcome of the study, leading to rejecting the null hypothesis.

H2: There is no correlation between perceived service quality and performance.
The results indicated that 24.8% of the variations in organizational performance are explained by perceived service quality, with a confidence level of 95%, nearly 75.2% is explained by other factors. In view of this one, the effect of perceived service quality, though significant, has low explanatory power on organizational performance which implies that hypothesis two did not accurately predict the outcome of the study, leading to rejecting the null hypothesis.

H3: There is no relationship between innovation with and performance of Kenya Airways.
According to the analysis, there is indication that 34.3% of the variation in organizational performance is explained by innovation, with accuracy level of 95%, nearly 65.7% is explained by other factors. The effect of innovation, though significant, has low explanatory power on organizational performance which implies that hypothesis two did not accurately predict the outcome of the study, leading to rejecting the null hypothesis.

H4: There is no correlation between differentiated benefits and performance
The results indicate that 11.8% of the variation in organizational performance is explained by differentiated benefits, with an accuracy level of 95%, nearly 88.2 percent is explained by other factors. The effect of differentiated benefits, though significant, has low explanatory power on organizational performance. This suggests that the hypothesis did not accurately predict the outcomes of the study, leading to rejecting the null hypothesis.

H5: There is no significant relationship will be found between cost strategies and performance of Kenya Airways
According to the study, there is evidence that 39.1 percent of the variations in organizational performance are explained by cost strategies, with accuracy of 95%, nearly 60.9% are explained by other factors. It is apparent that the independent effect of cost though significant, has low explanatory power on organizational performance, indicating that hypothesis five did not accurately predict the outcome of the study, leading to rejecting the null hypothesis.

These findings are similar to studies done in the past where emphasis was more on the effects of variables on organizational performance. Chandler (1962), for example, looked at strategy and structure. Boeker and Goodstein (1991) studied the relationship between environment and organizational performance. In all these studies, it was established that the variables have significant effect on organizational performance.

4.0 Conclusions

The study concludes that positioning is firmly placed within the general segmentation-targeting-positioning framework at Kenya Airways and positioning plays a pivotal role in marketing strategy, since it links market analysis, segment analysis and competitive analysis to internal corporate analysis. The measures of performance that affect marketing positioning strategies at the airline include employee turnover, increase in aircraft, increase in routes, increase in revenue/profitability.

Product differentiation at Kenya Airways involves differentiating it from competitors' products as well as one's own product offerings in order to enhance firm performance. Kenya Airways adopt the product differentiation strategy of packaging of goods in a creative way and incorporating new functional features in a bid to improve its performance. Product differentiation at Kenya Airways is done in order to demonstrate the unique aspects of their product and create a sense of value which guarantees better performance. The roles of cost strategies that are very important in enhancing the performance of Kenya Airways are such as informing and education of the market, increase in sales, maintaining or improving market share, creating or improving brand recognition and creation of a competitive advantage relative to competitor's products or market position. Kenya Airways use s*ponsorship,* advertising, sales promotion and personal selling as a means of achieving better performance. The study also concludes that that pricing strategies affect performance outcome and that other than table- locating prices, other forms of pricing policy are not regarded as unfair.

The study also concludes that that Kenya Airways adopt various issues in an attempt to better service quality including responsiveness, empathy, reliability, assurance and tangibles. The study found that the people that were very important in improving performance as relates to service quality were such as related companies, regulator(s) and customers. Organizational competitiveness supports service firms to provide high service quality to customers. Performance is associated with the development of new knowledge, which is crucial for firm innovation capability and firm performance. The distribution channels employed at Kenya Airways include indirect channels, service reliability, direct distribution channels and service quality. Kenya Airways uses various criteria in attempting to segment the market such as Psychographics and Geographic. The marketing performance indicators used in the organization include new customers acquired and collection of bad debts within customer relationships, demographic analysis of individuals (potential customers) applying to become customers and the levels of approval, rejections and pending numbers. The study finally concludes that there is a strong relationship between pricing strategies, perceived service quality, innovation, differentiated benefits, cost strategies and performance of Kenya Airways.

5.0 Recommendations

This study therefore recommends that in order to succeed, Kenya Airways should position itself favorably within a particular marketplace, relative to competitors which will enable it earn high rates of return or profits, irrespective of average profitability within the market and for Kenya Airways. The study also recommends that for the company to achieve better performance, the marketing executives must plan the product mix that will result in a combination of elements such as physical product, product services, brand and package desired by the target consumers.

The study also recommends that for Kenya Airways to be competitive it should provide high service quality to customers and markets in order to encourage a competitive advantage and receive quality to customers and markets and also receive a superior performance. Kenya Airways should also devise ways of overcoming the challenges that affects it in service quality such as consumers' limitation and consumers' loss of focus. The organization should also be innovative and closely monitor the competitors' actions in the market and should also be committed to learning which will give it greater innovation capability than competitors.

References

Aaker, D, Shansby, J. (1982). Positioning your product, *Business Horizons*, Vol. **25** pp.56-62.

Alba, J., Lynch, J., Weitz, B., Janiszewski, C., Lutz, R., Sawyer, A. and Wood, S. (1997). "Interactive home shopping: consumer, retailer, and manufacturer incentives to participate in electronic marketplaces", *Journal of Marketing*, Vol. **61**(3), pp.38-53.

Alden, D. L., Steenkamp, J .B. E. M. and Batra, R. (1999). "Brand positioning through advertising in Asia, North America, and Europe: the role of global consumer culture", Journal of Marketing, Vol. **63** (January), pp.75-87.

Andrews, K. R. (1971). The Concept of Corporate Strategy. Dow Jones- Irwin, Homewood, IL

Apostolidis, P., Kiulafas, K. K., Sohoritis, Y., Vlachakis, N. (1989), "The ABC's of positioning", Proceedings of the European Marketing Academy, Vol. **III** pp. 1063-77.

Arnott, D (1992). "Bases of Financial Services Positioning", Manchester Business School, Manchester, unpublished PhD thesis.

Arnott, D. C., Easingwood, C. J. (1994). Positioning in Services: An Hypothetical Typology of Competitive Bases, 23rd EMAC Conference Proceedings, Vol. 1, 17-20 May, University of Limburg, Maastricht, pp.1-3.

Aulakh, P. S., Kotabe, M. (1997). "Antecedents and performance implications of channel integration in foreign markets", *Journal of International Business Studies,* Vol. **28** (1), pp 145-75.

Avlonitis, G. J., Gounaris, S. P. (1997). "Marketing orientation and company performance – industrial versus consumer goods companies", *Industrial Marketing Management,* Vol. **26** pp.385-402.

Batra, R., Myers, J. G., Aaker, D. A. (1996), Advertising Management, 5th ed., Prentice-Hall, Upper Saddle River, NJ, pp. 190-216.

Bennion, M. L., Redmond, W. H. (1994). "Modeling consumer response in an industrial Commodity Market", *Industrial Marketing Management*, Vol. **23** pp 383-92.

Bingham, F. G, Raffield, B. T. (1995). Business Marketing Management, South-Western College Publishing, Cincinnati, OH.

Brooksbank, R. (1994), "The anatomy of marketing positioning strategy", Marketing Intelligence & Planning, Vol. **12** (4), pp. 10-14.

Buckley, P. J., Casson, M. C. (1998). "Analyzing foreign market entry strategies: extending the internationalization approach", Journal of International Business Studies, Vol. **29**(3), pp. 539-61.

Carroll, J. D., Green, P. E. (1997). "Psychometric methods in marketing research: part II multidimensional scaling", *Journal of Marketing Research,* Vol. **XXXIV** pp. 193-204.

Chandler, A. D., Jr. (1965). "Strategy and Structure"- Chapters in the History of Industrial Enterprise. MIT Press, Cambridge, MA.

Crant, J. M. (2000*).* "Proactive behaviour in organizations", *Journal of Management*, Vol. *26 (3),* pp. 435-62.

Day, G. S. (1994). "The capabilities of market-driven organizations", *Journal of Marketing,* Vol. **58**,

Devlin, J., Ennew, C. and Mirza, M. (1995). "Organisational positioning in retail financial services", Journal of Marketing Management, Vol. **11** (1-3), pp.119-32.

Dibb, S., Simkin, L., Pride, W. and Ferrell, O. (1994). Marketing: Concepts and Strategies, 2nd European ed, Houghton Mifflin, Boston, MA and London.

Dibb, S., Simkin, L., Pride, W. M. and Ferrell, O. C. (1997). Marketing: Concepts and Strategies, 3rd ed., Houghton Mifflin, Boston, MA.

Dickson, P. R. and Ginter, J. L. (1987). "Market Segmentation, Product Differentiation, and Marketing Strategy", *Journal of Marketing*, Vol. **51** (April), pp.1-10.

Dillon, W. R., Domzal, V. and Madden, T. J. (1986), "Evaluating alternative product positioning strategies", *Journal of Advertising Research*, pp.29-35.

Doney, P. M. and Cannon, J. P. (1997). "An examination of the nature of trust in buyer-seller relationships", *Journal of Marketing,* Vol. **61**, pp.35-51.

Dovel, G. P. (1990). "Stake it out: positioning success, step by step", **In** Hayes, H. M., Jenster, P. V., Aaby, N. E. (Eds), Business Marketing: A Global Perspective, Irwin, Chicago, IL, pp.270-8.

Doyle, P. and Saunders, J. (1985). "Market segmentation and positioning in specialized industrial markets", *Journal of Marketing*, Vol. pp. 24-32.

Doyle, P. and Wong, V. (1998). "Marketing and competitive performance: an empirical study", *European Journal of Marketing*, Vol. **32** (5/6), pp. 514-35.

Easingwood, C. J. and Mahajan, V. (1989). "Positioning of Financial Services for Competitive Strategy", *Journal of Product Innovation Management,* Vol **6**, pp. 207-19.

Fill, C. (1999). Marketing Communications: Contexts, Contents and Strategies, 2nd ed., Prentice Hall Europe, Hemel Hempstead, pp.511-22.

Galbraith, J. K. (1997). The New Industrial State, Penguin, Harmondsworth.

Golden, P. A., Johnson, D. M. and Smith, J. R. (1995). "Strategic Orientation and Marketing Strategies in Transition Economies: a study of Russian firms", *Journal of Strategic Marketing*, Vol. **3**, pp. 1-22.

Green, P. E., Krieger, A. M. (1989). "An Application of a Product Positioning Model to Pharmaceutical Products", *Marketing Science,* Vol. **11**(2), pp. 117-32.

Greenley, G. (1989). "An understanding of marketing strategy", *European Journal of Marketing*, Vol. **23** (8), pp.45-58.

Haas, R. W. (1995). Business Marketing: A Managerial Approach, 6th ed, South-Western College Publishing, Cincinnati, OH.

Harrison, T. (1987). A Handbook of Advertising Techniques, Kogan Press, London.

Hayes, H. M., Jenster, P. V., Aaby, N. E. (1996). Business Marketing: A Global Perspective, Richard D. Irwin, Chicago, IL.

Helfat, C. E. (2000). "Guest Editor's Introduction to the Special Issue: The Evolution of Firm Capabilities", *Strategic Management Journal,* Vol. **21** pp. 955-9.

Hooley, G., Saunders, J., Piercy, N .F. (1998). Marketing Strategy and Competitive Positioning, 2nd ed, Prentice-Hall, Hemel Hempstead.

Hooley, G. Saunders, J. (1993). Competitive Positioning: The Key to Market Success, Prentice-Hall, Hemel Hempstead.

Hooley, G., Broderick, A. and Muller, K. (1998). "Competitive positioning and the resource-based
Hooley, G., Greenley, G. (2005)."The Resource Underpinnings of Competitive Positions", *Journal of Strategic Marketing,* Vol. **13** (June), pp.93-116.

Hooley, G. J., Greenley, G., Fahy, J. and Cadogan, J. (2001), "Market Focused Revenues, Competitive Positioning and Firm Performance", *Journal of Marketing Management,* Vol. **17** (5-6), pp.503-52.

Hooley, G. J., Saunders, J. (1993). Competitive Positioning: The Key to Market Success, Prentice-Hall, London.

Hutt, M.D, Speh, T. W. (1998). Business Marketing Management: A Strategic View of Industrial and Organisational Markets, 6th ed, The Dryden Press, Orlando, FL.

Jenkins, M, le Cerf, E. and Cole, T. (1994), "Conceptualising Markets: An Exploration of Marketing Managers' Cognitive Frameworks", MEG Conference, pp.517-18.

Jobber, D. and O'Rilley, D. (1998), "Industrial Mail Surveys", *Industrial Marketing Management*, Vol. 27 pp.95-107.

Johar, J. S. and Sirgy, M. J. (1989). "Positioning Models in Marketing: Towards a Normative-Integrative model", *Journal of Business and Psychology*, Vol. **3** (4), pp.475-85.

Kald, M., Nilsson, F. and Rapp, B. (2000). "On strategy and management control: The importance.
Miles, R .E. and Snow, C. C. (1978). Organizational Strategy, Structure and Process, McGraw-Hill.

Kald, M., Nilsson, F. and Rapp, B. (2000). "On Strategy and Management Control: The Importance of Classifying Business", *British Journal of Management*, Vol. **11** pp.197-212.

Kalra, A. and Goodstein, R. C. (2002), "The Impact of Advertising Positioning Strategies on Consumer Price Sensitivity", *Journal of Marketing Research*, Vol. **XXXV** pp.210-24.

Kim, C. K. and Chung, J. Y. (1997)."Brand Polarity, Country Image, and Market Share: An Empirical Study", *Journal of International Business Studies,* Vol. **28** (2), pp.361-86.

Kohli, A, Jaworski, B. (1990). "Market Orientation: The Construct, Research Propositions and Managerial Implications", *Journal of Marketing,* Vol. **54**, pp.1-18.

Kotler, P. (1997). Marketing Management, 9th ed, Prentice-Hall, Englewood Cliffs, NJ.

Kotler, P (2000). Marketing Management, Millennium edition, Prentice-Hall, Upper Saddle River, NJ.
Kotler, P. (1999). Marketing Management, Analysis, Planning, Implementation and Control, 6th, Prentice-Hall, Englewood Cliffs, NJ.

Kotler, P. and Andreasen, A. (1999), Strategic Marketing for Nonprofit Organisations, Prentice-Hall International, London.

Kotler, P. and Kevin, L. K. (2006). Marketing Management (12 ed.). New Jersey: Prentice Hall.

Lehmann, D. R. and O'Shaughnessy, J. (1982). "Decision criteria used in buying different categories of products", *Journal of Purchasing and Materials Management*, Vol. **18** pp.9-14.

Lovelock, C. H. and Weinberg, C. B. (1984). Marketing for Public and Nonprofit Managers , John Wiley and Sons, New York, NY.

Morris, M. H. (1992). Industrial and Organizational Marketing, 2nd ed, Macmillan Publishing, New York, NY.

O'Cass, A., Grace, D. (2004), "Exploring consumer experiences with a service brand", *Journal of Product & Brand Management*, Vol. **13**(4), pp.257-68.

Park, C. W., Jaworski, B. J. and McInnes, D. (1986). "Strategic brand concept-image management", *Journal of Marketing,* Vol. **50** pp.135-45.

Pechmann, C. and Ratneshwar, S. (1991). "The use of comparative advertising for brand positioning: association versus differentiation", *Journal of Consumer Research*, Vol. **18** pp.145-60.

Porter, M. E. (1996). "What is strategy?", Harvard Business Review, pp.61-78.

Powers, T. L. (1991). Modern Business Marketing: A Strategic Planning Approach to Business and Industrial Markets, West Publishing Company, St Paul, MN.

Ray, M. L. (1992). Advertising and Communication Management, Prentice-Hall, Englewood Cliff, NJ.

Reeder, R. R., Brierty, E. G. and Reeder, B. H. (1987). Industrial Marketing: Analysis, Planning and Control, Prentice-Hall, Englewood Cliffs, NJ.

Ries, A. and Trout, J. (2000). Positioning: The Battle for Your Mind, McGraw-Hill, New York, NY.

Ries, A. L. and Trout, J. (1986). Positioning: The Battle for your Mind, McGraw-Hill, London.

Ries, A. L. and Trout, J. (1981), Positioning: The Battle for your Mind, McGraw-Hill, New York, NY.

Rossiter, J. R. and Percy, L. (1997), Advertising Communications & Promotion Management, 2nd ed., The McGraw-Hill Companies, New York, NY, pp.140-74.

Seggev, E. (1982). "Testing persuasion by strategic positioning", *Journal of Advertising Research,* Vol. **22** (1), pp.37-42.

Sekhar, K. M. (1989), "Positioning strategies for the British commercial vehicles", University of Strathclyde, Glasgow, unpublished MPhil thesis.

Sharp, B. and Dawes, J. (2001). "What is Differentiation and How Does it Work?," *Journal of Marketing Management,* **17**, pp 739-59.

Sivakumar, K. and Raj, S. P. (1997). "Quality tier competition: how price change influences brand choice and category choice", *Journal of Marketing,* Vol. **61**(3), pp.71-84.

Smith, R. W. and Lusch, R. F. (1976). *Journal of Advertising Research*, Vol. **16** (1), pp.37-43.

Smith, W. R. (1996). "Product Differentiation and Market Segmentation as Alternative Marketing Strategies", *Journal of Marketing*, Vol. **21** pp.3-8.

Stewart-Allen, A. L. (1999). "Do your international homework first", *Marketing News,* Vol. **33**(1), pp.25.

Trout, J., Rivkin, S. (1996). The New Positioning, McGraw-Hill, New York, NY.

Webster, F. E. (1991). Industrial Marketing Strategy, John Wiley and Sons, New York, NY.

Webster, F. E. Jr (1992). "The changing role of marketing in the organization", *Journal of Marketing*, Vol. **56** pp.1-17.

Wilson, D. T. (1995). "*An* integrated model of buyer-seller relationships", *Journal of the Academy of Marketing Science*, Vol. **23** (4), pp.335-45.

Wilson, E. J. and Woodside, A. G. (1995). "The relative importance of choice criteria in organizational buying: implications for adaptive selling", *Journal of Business-to-Business Marketing*, Vol. **2**(1), pp.33-57.

Woodside, A. G., Sullivan, D. P. and Trappey, R. J. (1999). "Assessing Relationships among Strategic Types, Distinctive Marketing Competencies and Organizational Performance", *Journal of Business Research,* Vol. **45**, pp. 135-46.

Wright, P., Kroll, M., Pray, B. and Lado, A. (1995). "Strategic Orientations, Competitive Advantage and Business Performance", *Journal of Business Research,* Vol. **33**, pp. 143-51.

www.kenya-airways.com, Company website accessed on 03-04-2010.

Zinnov L .L .C. (2007), Global aviation market - analysis. Challenges and opportunities for global carriers

SUB-THEME VII
AGRICULTURE AND VALUE-ADDITION

ISOLATION AND IDENTIFICATION OF ENDOPHYTIC BACTERIA OF BANANAS IN KENYA

C. N. ***Ngamau***[1]*, V. N.* ***Matiru***[2]*, C. W.* ***Muthuri***[3]*, A.* ***Tani***[4]
[1,2,3]*Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya*
[4]*Institute of Plant Science and Resources, Okayama University, Kurashiki, Okayama, Japan*
E-mail: cngamau@rpe.jkuat.ac.ke

Abstract
This study was conducted with the aim of isolating and identifying banana endophytic bacteria on the basis of their potential as biological fertilizer. Banana materials were collected from five different geographical regions to enhance diversity. Isolation of bacteria was done using five (5) different isolation media and the isolates were characterized on the basis of their morphology, biochemical and molecular characteristics. A total of 214 bacterial isolates were obtained and characterized. Microorganism profiling was done using MALDI-TOF/MS and the isolates were clustered into 53 genotypes. Based on their functional characteristics, 43 isolates were selected for 16S rRNA gene sequencing. The 43 strains showed varied levels of positive nitrogenase activity as measured by the acetylene reduction assay and 37 strains were observed to solubilize phosphates by the formation of visible dissolution halos on agar plates (NBRIP medium). Siderophore production of the isolates was determined using Chrome Azurol S (CAS) agar plates and all the isolates were observed to be positive for siderophore production with 3 strains showing distinctively high level of production. Using the 16S rRNA gene sequencing, the 43 strains were identified as *Serratia spp*. (17 strains), *Pseudomonas spp*. (12 strains), *Enterobacter spp*. (4 strains), *Rahnella spp*. (4 strains), *Raoultella spp*. (2 strains), *Bacillus spp*. (1 strain), *Klebsiella spp*. (1 strain), *Yersinia spp*. (1 strain) and *Ewingella spp*. (1 strain). In conclusion, banana endophytic bacteria were successfully isolated and identified, and some of the isolates showed potential of being biological fertilizers. However, greenhouse and field investigations are necessary to confirm this potentiality.

Key words: Endophytic bacteria, diazotrophic endophytes, phosphate-solubilizing microorganisms (PSM), banana

1.0 Introduction

Plants are naturally associated with mutualistic microorganisms that include endophytes. These are diverse microbes, including fungi and bacteria. They spend the entire or part of their life cycle living inside the plant causing no apparent symptoms of disease (Hallmann *et al*., 1997 and Long *et al.*, 2008). Although the interaction between endophytic bacteria and host plants has not been fully understood, it is well established that some of these interactions are beneficial to the plant (Long *et al.*, 2008; Rosenblueth and Martinez-Romero, 2006). The endophytes' close association with internal tissues of host plant has increasingly gained them scientific and commercial interest due to their potential to improve plant quality and growth (Carroll, 1992; Schulz *et al.*, 1998; Schulz *et al.*, 1999). Endophytic bacteria are of agronomic interest in that they can enhance plant growth in non-leguminous crops and improve their nutrition through nitrogen fixation, phosphate solubilization or iron chelation (Long *et al*., 2008).

Banana belongs to the family *Musaceae* in genus *musa* (Rossel, 2001). It is an excellent source of nutrients with a high consumer demand worldwide. It is the third world's most important starchy staple after cassava and sweet potato, and increased trade in local, regional and international markets has made it an important cash crop, and in some cases the only source of income for rural populations (Frison and Sharrock, 2001). In Kenya, area under banana production is about 84,000ha (MoA, 2006) with an estimated yield of 10 tonnes per hectare as opposed to a potential yield of over 40 tonnes per hectare (Karamura *et al*., 1998). Banana production in Kenya is constrained by, among others, declining soil fertility (Vanlauwe *et al*., 2005). This is brought about by insufficient application of manure due to cost implications especially for the farmers without livestock, and limited use of inorganic fertilizers. Soil erosion and export of nutrients in harvested banana parts e.g. bunches and pseudostems also contribute to the declining soil fertility. This problem can be addressed using chemical fertilizers. However, these are expensive and out of reach for most resource-poor farmers, who constitute the vast majority of banana farmers in Kenya.

Sustainable production of bananas in Kenya will therefore mean increasing their yield without the mass use of chemical fertilizers. It thus becomes of paramount importance to consider biological alternatives, which are cost effective and environment friendly. Some of these biological alternatives are the endophytic bacteria, which have beneficial characteristics to the cultivation of plants (Long *et al*., 2008, Ting *et al*., 2008). In Kenya, to the authors' knowledge, endophytic bacteria of banana have not been isolated or identified. Thus, there is no information on how they contribute, either individually or in mixtures, to banana growth and nutrition. A positive endophyte-banana association would reduce the use of agricultural inputs, such as fertilizer and pesticides, consequently saving on costs and reducing environment pollution.

The aim of this study was to isolate and identify endophytic bacteria from banana plants growing in Kenya and to determine their capacity to fix nitrogen, solubilize phosphates and produce siderophore *in-vitro*.

2.0 Materials and Methods

2.1 Sample Collection

Banana samples (roots, corm and stem) of two different banana cultivar groups (AAA - Cavendish & AAB - plantain) were collected from five different banana growing regions in Kenya namely Embu, Juja, Kisii, Maragua and Meru.

2.2 Surface sterilization

The banana samples were thoroughly washed in running tap water. Samples were then surface-sterilized using 70% ethanol for 2 minutes and immersed in 1.5% sodium hypochlorite plus a few

drops of Tween 20 for 5 minutes with shaking. The samples were then rinsed thoroughly in five changes of sterile distilled water and dried in sterile paper towels.

2.3 Isolation and Characterisation

Surface sterilised samples were macerated with a sterile mortar and pestle and then serially diluted in 12.5 mm potassium phosphate buffer at pH 7.1 (Zinniel *et al*., 2002). To target a wide range of endophytes, five different isolation media were used i.e. LGI solid media (Cavalcante and Dobereiner, 1988), nitrogen-free media (Dobereiner *et al.*, 1976), MacConkey (Rodriguez Caceres, 1982), YEM agar (Vincent, 1982) and nutrient agar. Morphological characterization was done on the basis of colony color, appearance, motility and gram staining. Biochemical characterization included Potassium hydroxide (KOH), catalase production, starch hydrolysis, gelatin hydrolysis, growth in 10% and 7% NaCl, citrate utilization, methyl red, urease and TSI agar tests.

2.4 Microorganism Profiling

Profiling of isolated bacteria was done using matrix-assisted laser desorption/ionization time of flight mass spectrometry (MALDI-TOF/MS, Bruker Daltonics). The ethanol/formic acid extraction procedure was used. Cluster dendrogram analysis was done and a MALDI tree constructed.

2.5 Screening for Nitrogenase Activity

The nitrogenase activity of the isolates was measured using the acetylene reduction assay (ARA). Ethylene production was determined on a Shimadzu Gas Chromatograph as described by Rogel *et al*., (2001).

Screening for phosphate solubilization: Qualitative screening of phosphate solubiliSation was done using the NBRIP growth medium (Nautiyal, 1999).

2.6 Detection of Siderophores

Siderophore production was detected using the Chrome Azurol S (CAS) agar plates as described by Schwyn and Neilands (1987). Orange halos around colonies on blue agar indicated siderophore excretion.

2.7 16S rRNA Gene Sequencing

Partial 16S rRNA gene amplification was done on the isolates that showed some functional potentiality using Eu8f AGAGTTTGATCCTGGCTCAG & Eu1492r GGCTACCTTGTTACGACTT primers. The PCR mixture composed of 0.1 µl Blend Taq Plus DNA polymerase, 2 µl dNTP, 2.5 µl Blend Taq Plus DNA polymerase buffer, 1 µl of each primer (12.5 µmol/ µl), 17.4 µl sterile MilliQ water and 1 µl sample DNA. The amplified 1.5 kb-product was purified using the MagExtractor and sequenced using EU8f AGAGTTTGATCCTGGCTCAG and EU518r GTATTACCGCGGCTGCTGG primers. The reaction mixture composed of 1.5 µl BigDye Ready Reaction Mix, 2.5 µl sequencing buffer (5x), 2 µl of 0.9 pmol/µl of each primer (EU8f and EU 518r [separately]), 3.5 µl sterile MilliQ water and 0.5 µl template DNA (Mag Extractor - purified PCR product).

2.8 Processing and Analysing of DNA Sequences

Obtained sequences were processed using the Staden Package software and BIOEDIT sequence alignment editor. Assembled sequences were analyzed at the Ribosomal Database Project site (http://rdp.cme.msu.edu/). Phylogenetic analysis was done using the Molecular Evolutionary Genetics Analysis (MEGA) software (http://www.megasoftware.net/).

3.0 RESULTS

3.1 Isolation and Selection

To target a wide range of endophytes, five (5) different isolating media were used. With this range of isolating media, a total of 2,717 isolates were initially obtained. On the basis of colony morphotypes, 214 representative isolates were selected. The selected isolates were further profiled using MALDI-TOR/MS (Figure 1). From the clusters obtained and on the basis of their functional characteristics, 43 isolates were selected for further characterization and identification.

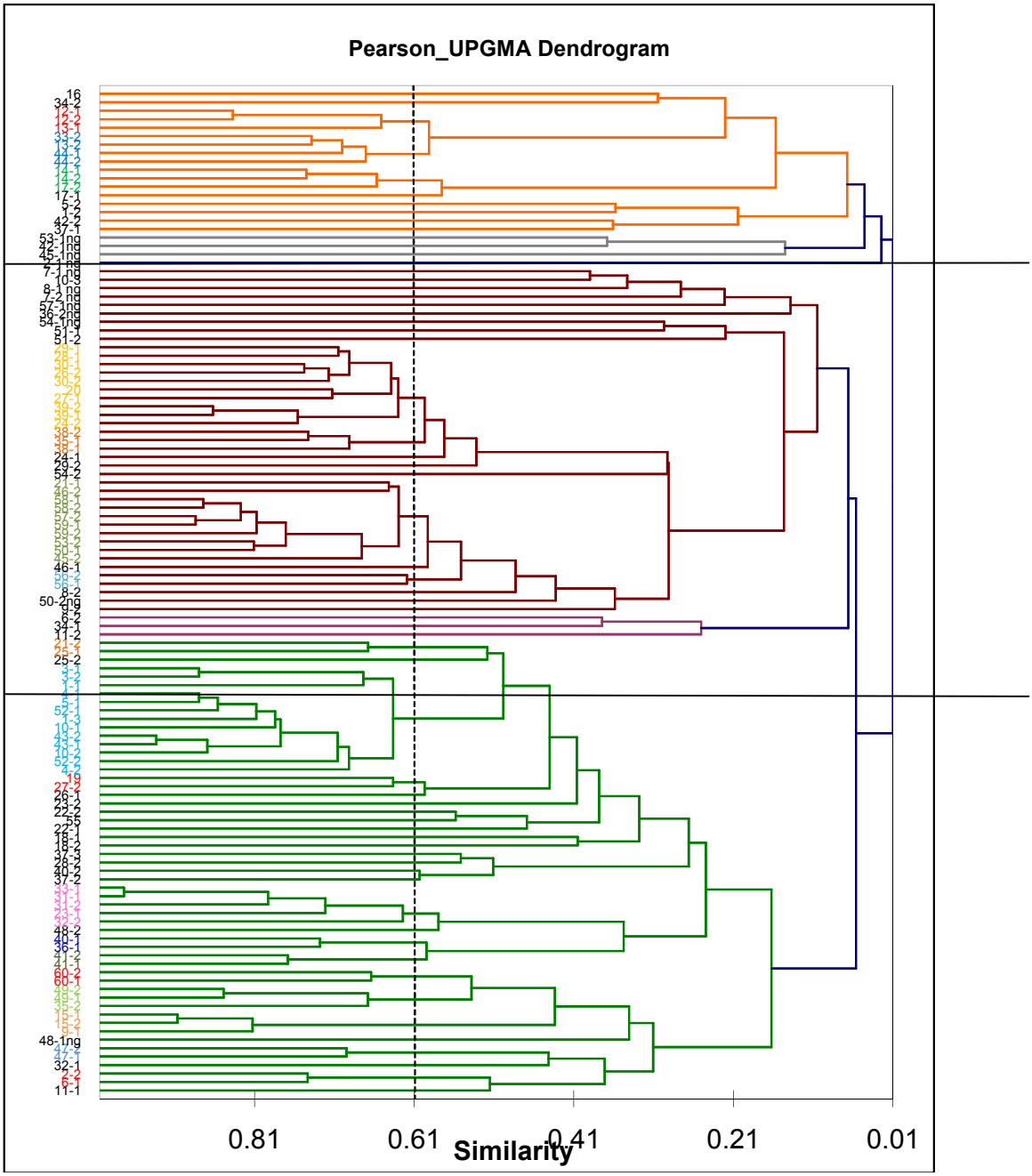


Figure 30: MALDI tree - microorganism profiling was done using MALDI-TOF/MS and isolates that showed similarity of up to 61% were clustered together. The isolates were clustered into 53 genotypes, which based on partial 16S rRNA gene sequencing could be grouped into three

(3) families (Bacillaceae at the top, Pseudomonadaceae at the middle and Enterobacteriaceae at the bottom)

3.2 16S rRNA Gene Sequencing

Phylogenetic analysis based on partial 16S rRNA gene sequencing allowed identification of the 43 selected isolates as *Serratia* spp. (17 strains), *Pseudomonas* spp. (12 strains), *Enterobacter* spp. (4 strains), *Rahnella* spp. (4 strains), *Raoultella* spp. (2 strains), *Bacillus* spp. (1 strain), *Klebsiella* spp. (1 strain), *Yersinia* spp. (1 strain) and *Ewingella* spp. (1 strain) (Table 1). The selected endophytic bacteria isolated from banana plants grown in Kenya in 2008/2009 can therefore be grouped into three (3) families namely *Bacillaceae, Enterobacteriaceae* and *Pseudomonadaceae* (Figure 1 and Table 1).

Table 1:Probable identification of 43 endophytic bacteria strains isolated from banana plants grown in Kenya in 2008/2009 based on partial sequencing of 16S rRNA gene. Similarity values with their 16S rDNA closest relatives ranged between 96% and 100%

Strain ID	*16S rDNA closest relative*	*Similarity*	*Strain ID*	*16S rDNA closest relative*	*Similarity*
14-1 (M9)	*Bacillaceae - Bacillus spp. "subtilis" subsp. "subtilis"*	99.7	26-1 (E15)	*Enterobacteriaceae - Serratia spp. "plymuthica"*	99.6
32-1 (E41)	*Enterobacteriaceae - Enterobacter spp. "amnigenus"*	99.4	22-1 (E13)	*Enterobacteriaceae - Serratia spp. "plymuthica"*	99.3
2-1 (J1)	*Enterobacteriaceae - Enterobacter spp. "hormaechei"*	99.2	22-2 (E13)	*Enterobacteriaceae - Serratia spp. "plymuthica"*	99.6
6-1 (J4)	*Enterobacteriaceae - Enterobacter spp. "ludwigii"*	100	18-2 (M20)	*Enterobacteriaceae - Serratia spp. "plymuthica"*	100
48-2 (K32)	*Enterobacteriaceae - Ewingella spp. "americana"*	99.5	18-1 (M20)	*Enterobacteriaceae - Serratia spp. "proteamaculans"*	98.6
49-1 (K22)	*Enterobacteriaceae - Klebsiella spp. "granulomatis"*	95.3	55 (K30)	*Enterobacteriaceae - Serratia spp. "proteamaculans"*	99.6
28-2 (E25)	*Enterobacteriaceae - Rahnella spp. "aquatilis"*	99.4	47-1 (K24)	*Enterobacteriaceae - Serratia spp. "ureilytica"*	98.1
37-2 (ME19)	*Enterobacteriaceae - Rahnella spp. "aquatilis"*	99.9	31-1 (E43)	*Enterobacteriaceae - Yersinia spp. "kristensenii"*	98.4
37-3 (ME19)	*Enterobacteriaceae - Rahnella spp. "aquatilis"*	99.9	9'-1 (M32)	*Enterobacteriaceae - Yokenella "regensburgei"*	99.5
40-2 (ME18)	*Enterobacteriaceae - Rahnella spp. "aquatilis"*	99.6	54-1 (K50)	*Pseudomonadaceae - Pseudomonas (Flavimonas) spp."oryzihabitans"*	99
60-2 (K29)	*Enterobacteriaceae - Raoultella spp. "terrigena"*	99.5	54-2 (K50)	*Pseudomonadaceae - Pseudomonas (Flavimonas) spp."oryzihabitans"*	98.9
48-1 (K32)	*Enterobacteriaceae - Raoultella spp. "terrigena"*	99.5	24-2 (E18)	*Pseudomonadaceae - Pseudomonas spp. "japonica"*	98.8

23-2 (E10)	*Enterobacteriaceae - Serratia spp. "fonticola"*	99.9	7'-2 (M28)	*Pseudomonadaceae - Pseudomonas spp. "koreensis"*	97.9
21-2 (E35)	*Enterobacteriaceae - Serratia spp. "fonticola"*	99.5	45-2 (K10)	*Pseudomonadaceae - Pseudomonas spp. "moraviensis"*	99.7
5-1 (J22)	*Enterobacteriaceae - Serratia spp. "fonticola"*		51-1 (K49)	*Pseudomonadaceae - Pseudomonas spp. "palleroniana"*	99.8
36-2 (ME10)	*Enterobacteriaceae - Serratia spp. "glossinae"*	99.3	51-2 (K49)	*Pseudomonadaceae - Pseudomonas spp. "palleroniana"*	99.8
40-1 (ME18)	*Enterobacteriaceae - Serratia spp. "glossinae"*	99	27-1 (E29)	*Pseudomonadaceae - Pseudomonas spp. "psychrophila"*	97.8
25-1 (E17)	*Enterobacteriaceae - Serratia spp. "glossinae"*	99.6	50-2 (K36)	*Pseudomonadaceae - Pseudomonas spp. "saponiphila"*	98.5
25-2 (E17)	*Enterobacteriaceae - Serratia spp. "glossinae"*	99.6	56-1 (K39)	*Pseudomonadaceae - Pseudomonas spp. "saponiphila"*	98.5
41-1 (ME8)	*Enterobacteriaceae - Serratia spp. "glossinae"*	99.2	59-1 (K23)	*Pseudomonadaceae - Pseudomonas spp. "savastanoi"*	97.3
43-1 (ME7)	*Enterobacteriaceae - Serratia spp. "glossinae"*	100	53-1 (K34)	*Pseudomonadaceae - Pseudomonas spp. "segetis"*	96.4
19 (E2)	*Enterobacteriaceae - Serratia spp. "plymuthica"*	99.6			

3.3 Functional Potentiality

The 43 isolates were selected on the basis of their potential ability to fix free nitrogen, solubilize phosphates and produce siderophore (Table 2). All selected isolates showed ability to fix free nitrogen, having grown in nitrogen-free media, but at varied degree as indicated by different ethylene peak areas in the Acetylene Reduction Assay (data not shown). 37 isolates were found to be positive for P solubilization with isolates 48-2 (K32) (*Ewingella* spp.), 37-2 (ME19) (*Rahnella* spp.), 40-2 (ME18) (*Rahnella* spp.) and 37-3 (ME19) (*Rahnella* spp.) showing the highest ability to solubilize P (Figure 2). All the isolates produced siderophore with highest production being observed with isolates 2-1 (J1) (*Enterobacter* spp.), 54-2 (K50) (*Pseudomonas* spp.) and 54-1 (K50) (*Pseudomonas* spp.) (Figure 3).

Table 2: Summary of the isolates' functional potentiality based on qualitative screening

Strain	*N-fixation ability*	*P-solubilization ability*	*Siderophore Production*
Bacillus spp. (1)	+	+	+
Enterobacter spp. (4)	+	+	+++
Ewingella spp. (1)	++	+++	+
Klebsiella spp. (1)	++	+	+
Rahnella spp. (4)	+	+++	+
Raoultella spp. (2)	++	+	+
Serratia spp. (17)	+	+	++
Yersinia spp. (1)	+	+	+
Pseudomonas spp. (12)	++	+	+++

Figure 2: Qualitative screening for phosphate solubilization using the NBRIP medium. Isolates 37-3 (ME19), 37-2 (ME19), 48-2 (K32) and 40-2 (ME18) showed the highest P-solubilization ability. Isolates 6-2 (J4), 5-2 (J22), 16 (M10) and 11-2 (M6) were found to be negative for P-solubilization and hence not among the 43 selected

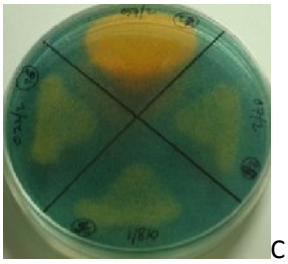
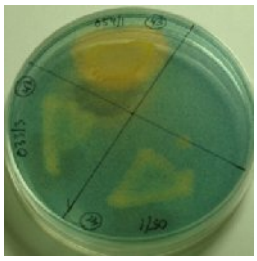
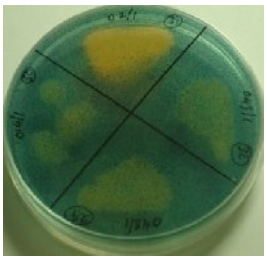
A A.B  C  D 

Figure 3: Qualitative screening for siderophore production on Chrome Azurol S agar plates. Plate A: All the 43 isolates on one agar plate for easy screening. Plates B to D: Showing the 3 isolates that showed highest siderophore production i.e. isolates 2-1 (J1), 54-2 (K50) and 54-1 (K50)

4.0 Discussion and Conclusions

Endophytic bacteria of bananas grown in Kenya were isolated and identified in respect to their potential as biofertilizers. The isolates could be grouped into three families i.e. *Enterobacteriaceae, Pseudomonadaceae* and *Bacillaceae*. The family *Enterobacteriaceae* was the most diverse with 7 genera i.e. *Serratia* (17 strains), *Enterobacter* (4 strains), *Rahnella* (4 strains), *Raoultella* (2 strains), *Klebsiella* (1 strain), *Yersinia* (1 strain) and *Ewingella* (1 strain). Both the *Pseudomonadaceae* and *Bacillaceae* family were represented by only one genus namely *Pseudomonas* (12 strains) and *Bacillus* (1 strain), respectively. *Serratia* and *Pseudomonas* species were the most abundant with 17

strains and 12 strains out of the 43 identified isolates, respectively. *Azospirillum, Burkholderia, Citrobacter, Herbaspirillum, Klebsiella, Pseudomonas* and *Serratia* species are among the bacterial endophytes that have been isolated from banana plants (Weber *et al*., 1999; Martinez *et al.*, 2003; Rosenblueth *et al.*, 2004; Ting *et. al*., 2007 and Weber *et. al*., 2007).

Isolates 48-2 (K32) (*Ewingella* spp.), 37-2 (ME19), 40-2 (ME18) (*Rahnella* spp.) and 37-3 (ME19) (*Rahnella* spp.) showed the highest potential as P solubilizers. According to Kim and others (1998b), *Rahnella aquatilis* has genes that are necessary for mineral phosphate solubilization. Isolates 2-1 (J1) (*Enterobacter* spp.), 54-2 (K50) (*Pseudomonas* spp.) and 54-1 (K50) (*Pseudomonas* spp.) showed high siderophore production. Gangwar & Kaur (2009) also reported *Pseudomonas spp*. isolated from ryegrass as high siderophore producer. None of the 43 isolates showed exceptionally high nitrogen fixing ability. The commonly reported endophytic diazotrophic bacteria of banana include; *Azospirillum*, *Burkholderia,* and *Herbaspirillum* species (Weber *et al*., 1999 and Weber *et al*., 2007), of which none was identified in the current study.

In conclusion, isolates 48-2 (K32) (*Ewingella* spp.), 37-2 (ME19) (*Rahnella* spp.), 40-2 (ME18) (*Rahnella* spp.), 37-3 (ME19) (*Rahnella* spp.), 2-1 (J1) (*Enterobacter* spp.), 54-2 (K50) (*Pseudomonas* spp.) and 54-1 (K50) (*Pseudomonas* spp.) can be qualified as potential biofertilizers and greenhouse and field investigations are recommended for confirmation of this potentiality.

Acknowledgements
The authors wish to thank the Research, Production and Extension Division of JKUAT and the JSPS-AASPP program, Japan for sponsoring this study. Special appreciation also goes to the banana farmers in Juja, Maragua, Embu, Meru and Kisii for allowing us access to their fields for sampling. Accessing the farmers would have been difficult without the assistance of the respective agricultural officers, we are therefore very grateful to them. The authors would also like to acknowledge the JKUAT departments of Botany, Horticulture and Food Science & Technology, the Institute of Biotechnology Research at JKUAT and the Institute of Plant Science and Resources, Okayama University for availing their lab facilities for this study. We also thank the project's research assistants i.e. Mr. Julius Mugweru and Mr. Joseph Muthanga for their persistent dedication to the success of this study. Special appreciation also goes to Dr. Nurettin Sahin, Associate Professor, Mugla University, Turkey for his assistance in phylogenetic analysis.

References

Carroll, C. G. (1992). Fungal mutualisim.in Carroll, C. G. and Wicklow, D. T. Book Fungal mutualisim. NewYork, Dekker, pp 327-254.

Cavalcante VA and Dobereiner J. (1988). A new acid tolerant nitrogen-fixing bacterium associated with sugarcane. Plant and Soil **108**, pp 23-31.

Dobereiner J, Marriel I. E. and Nery M. (1976). Ecological distribution of Spirillum lipoferum Beijerinck. *Can J. Microbiol*., **22, pp** 1464-1473.

Frison E. and Sharrock S. (2001). The economic, social and nutritional importance of banana in the world. In: Banana and food security (Frison and Sharrock eds.). International symposium Pp 21-35 Dovala, Cameroon.

Gangwar, M. and Kaur, G. (2009). Isolation and characterization of endophytic bacteria from endorhizosphere of sugarcane and ryegrass. *The Internet Journal of Microbiology*, **7**(1).

Hallmann, J., Quadt-Hallmann, A., Mahaffee, W. F., and Kloepper, J. W. (1997). Bacterial endophytes in agricultural crops. C*an. J. Microbiol*., **43**, pp 895-914.

Karamura E. B., Karamura D. A. and Sharrock S. (1998). Banana production systems in Eastern and South Africa. Banana and Food Security. International Symposium. Pp 104 - 110. Douala, Cameroon November 1998.

Kim K. Y., Jordan D. and Krishnan H. B. (1998b). Expression of genes from Rahnella aquatilis that are necessary for mineral phosphate solubilization in Escherichia coli. FEMS Microb. Lett. 159, 121–127.

Long, H. H., Schmidt, D. D. and Baldwin, I. T. (2008). Native Bacterial Endophytes Promote Host Growth in a Species-Specific Manner; Phytohormone Manipulations Do Not Result in Common Growth Responses, PLoS ONE 3(7): e2702. doi:10.1371/journal.pone.0002702. 2009.

Martinez L, Caballero-Mellado J, Orozco J and Martinez-Romero E. (2003). Diazotrophic bacteria associated with banana (Musa spp.). *Plant and Soil*, **257**: 35-47.

Nautiyal, C. S. (1999). An efficient microbiological growth medium for screening phosphate solubilizing microorganisms. FEMS Microbiology Letters, **170**, pp 265–270.

Rodriguez Caceres E. A. (1982). Improved medium for isolation of Azospirillum spp. Appllied and Environmental Microbiology **44**, pp 990 - 991.

Rogel M. A., Hernandez-Lucas I., Kuykendall L. D., Balkwill D. L. and Martinez-Romerol E. (2001). Nitrogen-fixing nodules with Ensifer adhaerens harboring Rhizobium tropici symbiotic plasmids. *Applied and Environmental Microbiology*, **67**, pp 3264 - 3268.

Rosenblueth, M., and Martínez-Romero, E. (2006). Bacterial Endophytes and Their Interactions with Hosts. *The American Phytopathological Society* Vol. **19**,(8), 2006 / 827.

Rosenblueth, M., Martinez, L., Silva, J., and Martinez-Romero, E. (2004). Klebsiella variicola, a novel species with clinical and plant-associated isolates. *Syst. Appl. Microbiol*. **27**, pp 27-35.

Rossel G. (2001). The history of plantain in Africa; a taxonomic - linguistic approach. In: Banana and food security. Frison and Sharock (eds). International symposium. Douala, Cameroon. Pp 181 - 195.

Schulz, B., Guske, S., Dammann, U. and Boyle, C. (1998). Endophytes host interactions. II. Defining symbiosis of the endophyte-host interaction. Symbiosis, **25**, pp 213-227.

Schulz, B., Rommert, A. K., Dammann, U. and Aust, H. J. (1999). The endophyte-host interaction: A balanced antagonism? *Mycol. Res* **103**(10):, pp 1275-1283.

Schwyn, B. and Neilands, J. B. (1987). Universal Chemical Assay for the Detection and Determination of Siderophores. *Analytical Biochemistry,* **160**, 47-56.

Ting, A. S. Y., Meon, S., Kadir, J., Radu, S. and Singh, G. (2008). Endophytic microorganisms as potential growth promoters of banana*. Bio Control,* **53**, pp 541-553.

Vanlauwe B., Sanginga N., Jefwa J., Kahangi E., Rutto L. K., Odee D., Gichuki C., Kibugu E., Mubiru D., Ssali H., Van Asten P., Okech S., Gold C., Elsen A. (2005). Exploration of Integrated Soil fertility management for banana production and marketing in Uganda and Kenya: Arbuscular Mycorrhizal Fungi help establishment and production of tissue culture banana – Final report phase I –January 2004 – February 2005.

Vincent JM. (1970). A manual for the practical study of root-nodule bacteria. IBP handbook No. 15.

Weber, O. B., Baldani, V. L. D., Teixeira, K. R. S., Kirchhof, G, Baldani, J. I. and Dobereiner, J. (1999). Isolation and characterization of diazotrophs from banana and pineapple plants. *Plant and Soil,* **21,** pp 103-113.

Weber O. B., Muniz C. R., Vitor A.O., Freire F. C. O. and Oliveira V. M. (2007). Interaction of endophytic diazotrophic bacteria and oxysporum f. sp. cubense on plantlets of banana 'Maca'. *Plant Soil*, **298**, pp 47-56.

Zinniel D. K., Lambrecht P., Harris N. B., Feng Z., *et al*. (2002). Isolation and characterization of endophytic colonizing bacteria from agronomic crops and prairie plants. *Appl. Environ. Microbiol.* **68**, pp 2198-2208.

EFFECT OF NITROGEN AND SILICON ON MANAGEMENT OF RICE BLAST (*PYRICULARIA ORYZAE*) IN MWEA IRRIGATION SCHEME OF KENYA

C. W. Muriithi[1], E. N. Mugai[2] and A. W. Kihurani[3]
Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: cmuriithi2005@yahoo.com

Abstract
Plant health is an important factor for plant growth and development. Nitrogen is essential and is usually required in large quantities by plants. However, many studies have shown that high nitrogen concentration in plant increases the severity of disease infection by plant pathogen. On the other hand, silicon though regarded as non essential element, has several benefits in crop growth. Its application to the rice plant has been shown to increase resistance to rice blast *Pyriularia oryzae* as well as increased crop yield. This study aimed to establish an effective level of nitrogen and silicon in the management of the rice blast disease. The experiment was carried out at Mwea Irrigation Agricultural Development (MIAD) research station in Kirinyaga District. Seedlings were raised in the nursery before culturing in vertisol filled pots with various treatment combinations of nitrogen (40, 80 and 120 kgN ha^{-1}) and silicon (0,500, 1000 and 1500 kgSi ha^{-1}) in split plots and in completely randomized design (CRD). Plants were inoculated after two weeks with the *Pyricularia oryzae* spore after transplanting and disease assessed in a scale of (0-9) according to IRRI standard. Higher rice blast was realised at 120 KgN and 0kgSi ha^{-1} and in the plots that had neither nitrogen nor silicon. The organic husk ash at $2ton^{-1}$ before burning and $0.7ton^{-1}$ was shown to be good source of silicon and gave results equivalent to those of 120KgN and 1000KgSi.combination.The study established that interaction of nitrogen and silicon at 80 kgN ha^{-1} and 1000 kgSi ha^{-1} was the optimal rate for management of the rice blast disease.

Key words: Silicon, nitrogen, rice blast, rice, hush ash

1.0 Introduction

Rice (*Oryza sativa* L) is a staple food of nearly one-half of world's population contributing high calorie intake to humans. (FAO, 2004) In Kenya it is among the important cereals ranking third after maize and wheat (MOA, 2007). From the varieties grown in Mwea, Basmati 370 is the most preferred by many growers as it fetches higher returns. However, this cultivar is susceptible to rice blast disease which is one of the most important rice diseases that can cause a considerable yield loss. Awoderu, (1990) found over 70 percent yield loss caused by rice blast. In Western Kenya the disease was found to cause a loss of 50% (Anon, 1992). There are various strategies undertaken in management of rice blast that include cultural method, use of resistant varieties, plant nutrition and chemical control. Among these strategies plant nutrition is more appealing as it is considered environmentally friendly. Nitrogen is an essential element in plant growth and development but as reported by Kurschner *et al.,* (1992) high nitrogen concentration in plants increase the severity of infection by obligate parasite. Nitrogen supply influences branching and leaf expansion which together determines the canopy size. A large canopy is conducive to spore transfer and pathogen infection than in sparse canopies. Silicon on the other hand is an important element although it is not classified as an essential element. As reported by Datnoff *et al*., (1990) and Datnoff *et al*., (2001) large amount of silicon has been seen to accumulate in some crops like rice and other grasses. Rice containing inadequate silicon is severely infected by rice blast. In order to manage rice blast disease through plant nutrition there was need to determine effective rates of nitrogen and silicon as important elements curb the disease.

2.0 Materials and Methods

2.1 Rice Culture and Treatment Application

Two experiments were conducted for two seasons (November 08 and May 09). Soil used in the experiment was alluvial soil type that is usually suitable for rice production in Mwea Division. It was obtained from Mwea Irrigation Agricultural Development (MIAD) field and analyzed for nitrogen, phosphorus, potassium and silicon to determine the initial concentration in the soil. Certified seed was sown in the nursery which was preceded by seed treatment through soaking and incubation (pre-germination). Soaking was done for 24hrs while pre-germination took 3 days before sowing. Seedlings were later transplanted into plastic bags after twenty eight days.

2.2 Treatments Rates of Nitrogen and Silicon

The experiment was arranged in Split plot design laid in complete randomized design (CRD) replicated four times. There were seventeen treatments that included four levels of silicon (0, 500, 1000 and 1500Si kg ha^{-1}), four nitrogen levels (0, 40, 80 and 120NKg ha^{-1}) and 2tons of ash husk. Calcium silicates was the source of silicon at 0, 2500, 5000 and 7500kg ha^{-1} This translated to 0, 0.06,0.12,0.18gCasio3/ 200 g soil per pot respectively. Sulphate of ammonia (SA) was the source of nitrogen at (0, 0.46,0.91 and 1.37 gm/pot). The potassium and phosphorus were applied as basal fertilizer at recommended rates of 30 Kg K_2O ha^{-1} and 58 kgP_2O_5 ha^{-1}. Due to the calcium contained in the calcium silicate as the source of silicon the calcium element was added to ensure the effect of silicon was not influenced by calcium. Individual treatments were thoroughly mixed with 200 gms of soil, filled in plastic pots (12x8cm). Each of the units/treatment contained six plants replicated four times. The mixture was well-irrigated four days before the seedlings were transplanted. The seedlings that were of the same height and thickness were selected for uniformity purposes.

2.3 Preparation of Media

The media was prepared by dissolving 35.5 gms of malt extract agar (MEA) in 1 litre of distilled water and mixed on hot plate/stirrer, mixed homogeneously before autoclaving /sterilizing for 15 min at 121^0C. The media was supplemented with 0.05g Chlorotetracycline, 0.1g penicillin G and 0.2 g Streptomycin-sulphate per litre to prevent bacterial contamination. The media was dispensed into

culture plates after attaining a temperature of 30-40^{o}C. It was then allowed to cool, gel and preserved for culturing.

2.4 Preparation of Inoculums

Infected plant tissues were collected from MIAD and the surrounding infected fields as the source of inoculums. The conidia (asexual spores) were harvested from different plant parts (stems, panicles, sheaths), washed thoroughly with tap water. Under aseptic conditions, the infected plant tissue were cut in small section 5-10mm square from the margin of the infected lesion such that it contained both diseased and healthy looking tissue. The tissues were surface sterilized for two minutes in 90% Ethanol, washed with three changes of sterile water and blotted dry on clean sterile paper by use of forceps and finally plated in 90mm Petri dishes containing malt extract agar (MEA)**.** The cultured media was incubated under continuous light at 25°C for 24 hours after which the light was put off and incubation continued for seven days allowing the growth of mycelia. Under sterile condition a drop of sterile water was put on the slide and a small piece of mycelia placed on it, covered with a cover slip and placed under a light microscope for observation. After the identification of the fungus, the pathogen was sub-cultured in order to isolate rice blast fungus and accelerate the sporulation. The Petri dishes were re-incubated in the laboratory for seven days during which growing fungi were viewed under a light microscope (x40 magnification). Further sub-culturing was done to obtain pure cultures.

2.5 Pathogenesity Tests

Once the pathogen was identified and isolated, pathogenesity test of the fungi was necessarily for verification that the fungus was the real cause of the rice blast disease. This was done through inoculation of grown plants in the screen house. The method used was as described by Matsuo and Hoshikama, (1993). The soil was collected from the field, heat sterilized (121^{o}C, 102 kPa, and 60 min) and allowed to cool before potting in the plastic containers (200gms volume). The plants were planted in two different pots of which one pot was inoculated while the other was left with healthy plants. Distilled water was used to flood the soil as required by rice plant. The inoculums were foliar sprayed by use of a hand sprayer on the plants in one pot and then covered with a plastic bag to maintain the water-saturated atmosphere. The plastic bag was removed after 24hours after which the plants were left at room temperature. The other pot was left with clean plant without any inoculation. The infection from the fungus was observed four days after inoculation. The symptoms of the lesions that appeared on the leaves of the inoculated plants were similar to the symptoms described on the naturally infected plants from the field. The plant parts of the other plants that were not inoculated were surface sterilized with 95% ethanol for 1 to 2 min. Similarly the infected plants parts too were surface sterilized the same way and placed on the malt extract agar media and incubated for 24 hours of light and observed on the seventh day. The fungus was observed in the infected plants while it was absent in the healthy parts.

2.6 Inoculation

Inoculation was done at the time of emergence on the seventh leaf from the main tiller as described by Matsuo and Hoshikama (1993). A conidial suspension of *Pyricularia oryzae* (4×10^4 conidia/ ml) was used. This was achieved by placing a cover slip over the hemocytometer counting chambers. By use of a Pasteur pipette a drop of conidia suspension was placed at the edge of the V-shaped allowing the suspension to be drawn into the chamber by capillary action. One of the nine 1mm square represented a volume of 10^{-4}mls. Using the 10X objective the conidia of 1mm square area was counted using tally counter. The conidia amounted to more than100 conidia per 1mmsquare area. Other four squares were counted and calculated using a formula: c=n/v where c=conidia concentration in conidia/ml, n=average number of conidia/square mm, v=volume counted=$10^{-4.}$ Thus: c=nx10^4. This suspension was applied as a fine mist to the upper leaf blades of six plants per pot until runoff with a hand sprayer. Gelatin (1%, wt/vol) was added to the sterile water to aid

conidial adhesion to the leaf blades. Immediately after inoculation, plants were covered with a plastic bag to increase humidity for 24 hrs. The pots that contained the plants were retained with water to maintain high relative humidity of approximately 85% and above throughout the experiments.

2.7 Disease Assessment

The data regarding the occurrence of the rice blast disease was collected one week after the inoculation by using the disease rating scale 0-9 developed by International Rice Research Institute (IRRI, 2002). Four plants were randomly selected out of the six plants planted in a pot. The fourth leaf was tagged in each of the selected plant and the largest lesion measured in both width and length. Area under the disease progress curves (AUDPC) was used for disease determination where the lesion size was measured using the formula.

Lesions area= width/15 [(6*length) +8{square root (width2+length2)/4}] as described by Pinnschmidt *et al.* (1993)

Table 1: Visual score rating for disease and plant response

Code	*Type of lesions*	*Host Behavior*
0	No lesions observed	Highly resistant
1	Small brown specks of pinpoint size or larger brown specks without sporulating center	Resistant
2	Small roundish to slightly elongated, necrotic gray spots, about 1-2 mm in diameter, with a distinct brown margin	Moderately resistant
3	Lesion type is the same as in scale 2, but a significant number of lesions are on the upper leaves	Moderately resistant
4	Typical susceptible blast lesions 3 mm or longer, infecting less than 4% of the leaf area	Moderately susceptible
5	Typical blast lesions infecting 4-10% of the leaf area	Moderately susceptible
6	Typical blast lesions infection 11-25% of the leaf area	Susceptible
7	Typical blast lesions infection 26-50% of the leaf area	Susceptible
8	Typical blast lesions infection 51-75% of the leaf area and many leaves are dead	Highly susceptible
9	More than 75% leaf area affected	Highly susceptible

Sources: International Rice Research Institute (2002). *Standard evaluation systems for rice*

2.8 Data Analysis

Data on rice infection of plant by rice blast was analyzed using statistical package (SAS,2001). The analysis conducted were (ANOVA) and means separations using LSD.

3.0 Results and Discussion

The results in figure 1 indicate that infection rate in the first sampling date did not show any significant ($P > 0.05$) difference, implying that all the plants acquired the same score with a mean of 1. However, the subsequent weekly sampling that followed indicated significant ($P< 0.05$) difference among different levels of nitrogen all through to the last sampling. Nitrogen applied at 120Kg ha^{-1} (N3) gave a higher level of rice blast infection while a lower infection was realized in those plots that were treated with husks ash at 2tons ha^{-1}.

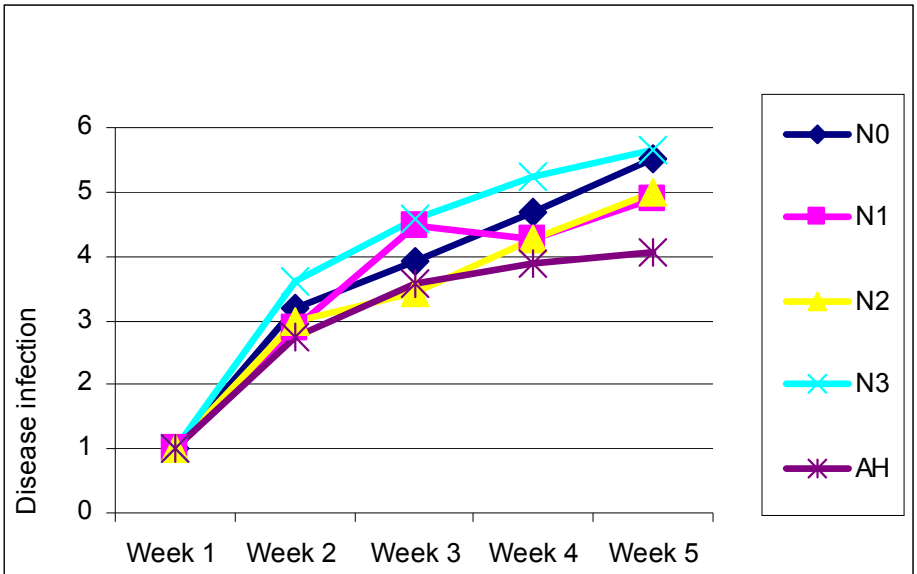


Figure 1. Effect of Ntrogen on Rice blast disease

As was the case of nitrogen, the results shown in figure 2 indicated that silicon levels did not show any significant ($P > 0.05$) difference in the first sampling period. The second and the subsequent sampling showed significant ($P < 0.05$) difference in the level of infection. Infection was higher where there was no silicon (S0) and on a lower rate 500 Kg Si ha^{-1} (S1) of application while the least infection of rice blast occurred where silicon was applied at 1500 kg Si ha^{-1} (S3) and 1000Kg Si ha^{-1} (S2). Disease infection decreased with increase in silicon rate. Husk ash applied at 2tons ha^{-1} (0.7 tons ha^{-1}) managed the rice blast at a higher level than 500 Kg Si ha^{-1} (S1) Figure 2. Contrary to nitrogen, high silicon level decreased the rice blast infection.

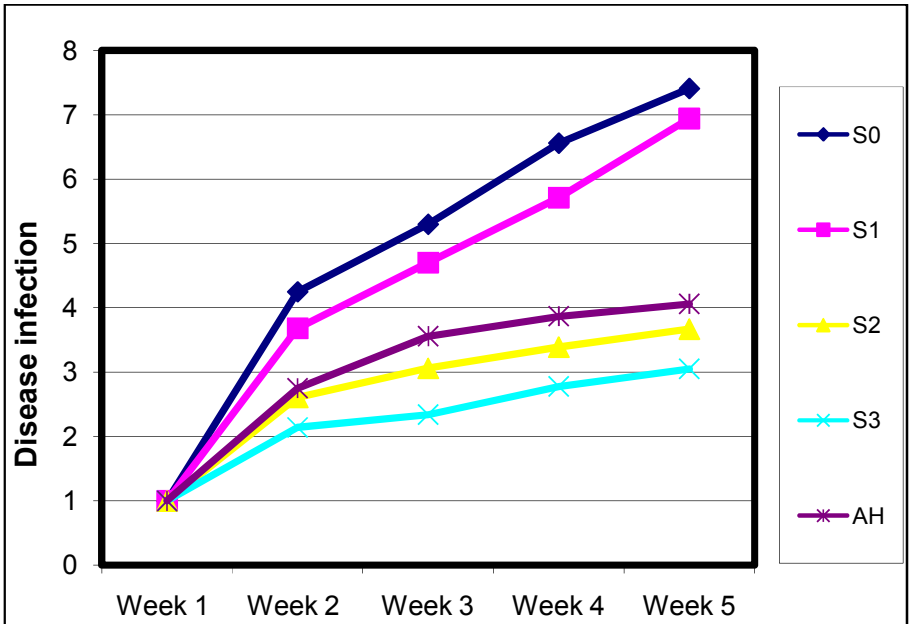


Figure 2. Effect of Silicon levels in management of Rice blast

The results (Table 2) for interaction of nitrogen and silicon in the first season indicated that the plots that had no silicon (0KgSi ha^{-1}) or nitrogen (0 KgN ha^{-1}) N0S0 experienced a higher rice blast infection. Similarly 80 KgN and 0 KgSi ha^{-1} (N2S0), 0 KgN and 500 KgSi ha^{-1} (N0S1), 40 KgN and 500 KgSi ha^{-1} (N1S1), 40 KgN and 0 KgSi ha^{-1} (N1S0), 80 KgN and 500 KgSi ha^{-1} (N2S1) gave a disease mean score above 7 indicating the plants were susceptible to the pathogen. These results revealed low nitrogen and low silicon might have contributed to increase of rice blast infection of rice plants. However, husk ash at 2tons ha^{-1} and 0KgN and 1000SiKg ha^{-1} /ha (N0S2) were moderately susceptible. Plots treated with 80 KgN and 500 SiKg/ha (N2S1), 80KgN and 1500 SiKg ha^{-1} a (N2S3), 120 KgN and 1000SiKg ha^{-1} (N3S2), 120 KgN and 1500 SiKg/ha (N3S3) showed the plants were moderately resistant to the pathogen. That disease was well managed at 80 KgN, 1000 SiKgha^{-1} (N2S2) and 80 KgN and 1500 SiKg ha^{-1} (N2S3) which were not significantly differently with a mean score of 2-3 (moderately resistant). The trend was similar in the second season although the means in the second season were higher (Table 3). The plots that weretreated with the husk ash were not significantly different from those treated with 120 KgN and 1000 SiKgha^{-1} (N3S2).

Table 2: Interaction of nitrogen silicon and husks ash in management of rice blast season one

Nitrogen	*Silicon*	*Sampling period*			
		Week 1	*Week 2*	*Week 3*	*Week 5*
AH	AH	2.75**d**	3.56**e**	3.88e	4.06**g**
N0	S0	4.06**b**	5.00**bc**	6.31**b**	7.31abc
N0	S1	3.75**b**	4.88**c**	5.81**c**	7.19c
N0	S2	2.81**d**	3.56**e**	4.00**e**	4.63**f**
N0	S3	2.13**e**	2.19**g**	2.63g	2.94lk
N1	S0	3.81**b**	4.69**c**	6.25**b**	7.25bc
N1	S1	3.19c**d**	4.19**d**	5.13**d**	6.25**e**
N1	S2	2.56**d**	2.94**f**	3.25**f**	3.38**ij**
N1	S3	2.00**e**	2.06**g**	2.44**g**	2.69**l**
N2	S0	4.63**a**	5.38**b**	6.69**ab**	7.38abc
N2	S1	3.31**c**	4.00**d**	5.13**d**	6.69**d**
N2	S2	2.06**e**	2.25**g**	2.63**g**	2.88**l**
N2	S3	2.00**e**	2.19**g**	2.69**g**	3.00**lk**
N3	S0	4.50**a**	6.13**a**	7.00**a**	7.60**ab**
N3	S1	4.50**a**	5.75**ab**	6.81**a**	7.63**a**
N3	S2	3.00**cd**	3.50**e**	3.69**eg**	3.81**gh**
N3	S3	2.44**de**	2.94**f**	3.38**f**	3.67hi

Means of the same letter along the column are not significantly different

Table 3: Interaction of nitrogen silicon and ash husks in management of rice blast season 2

Nitrogen	*Silicon*	*Sampling period*			
		Week 1	*Week 2*	*Week 3*	*Week 5*
AH	AH	2.63**d**	3.63**d**	3.94**d**	4.13**f**
N0	S0	4.06**b**	5.31**bc**	6.50**b**	7.19**c**
N0	S1	3.75**b**	4.94**c**	6.13**b**	7.06**c**
N0	S2	2.81**d**	3.56**d**	4.19**d**	4.69**e**
N0	S3	2.19**e**	2.50**f**	2.81**f**	3.00**ih**
N1	S0	3.75**b**	5.06**c**	6.25**b**	7.25**bc**
N1	S1	3.18**cd**	4.50**c**	5.31**c**	6.05**d**
N1	S2	2.60**d**	3.00**e**	3.44**e**	3.75**g**
N1	S3	2.00**e**	2.19**f**	2.63**f**	2.75**i**
N2	S0	4.56**a**	5.56**b**	6.81**ab**	7.55**ab**
N2	S1	3.31**c**	4.00**d**	5.19**c**	6.56**d**
N2	S2	2.00**e**	2.25**f**	2.69**f**	2.94**ih**
N2	S3	1.87**e**	2.19**f**	2.75**f**	3.00**ih**
N3	S0	4.63**a**	6.25**a**	7.06**a**	7.75**a**
N3	S1	4.50**a**	5.81**ab**	7.00**a**	7.63**a**
N3	S2	3.00**cd**	3.63**d**	3.94**d**	4.25**ih**
N3	S3	2.50**d**	2.88**ef**	3.25**e**	3.56**h**

Means of the letter along the column are not significantly different

The mean score of the first observation was the same in all the treatments which may have indicated that all the plants were similarly infected once the inoculums was introduced. It was likely that the disease was still latent hence no physical symptoms were detected. The trend indicated that as the level of nitrogen increased the infection of rice blast also increased with highest infection occurring at 120 KgN ha^{-1}. This might have been brought about due to creation of canopy providing a suitable environment for the rice blast to thrive. Although the application was done in two split the infection at this rate was high. These results disagreed with what was found by Helms, (1990); Kurschner *et al.,* (1992) who found that splits application of nitrogen reduced the rice blast severity. This implied that as long as the nitrogen is excessive, the disease tend to increase. The soil in Mwea being vertisols could have had little leaching and probably the first split had not been exhausted by the time the second split was applied. Since the rice plants were grown in the pot there was no likelihood of leaching of nitrogen hence retaining high amount of nitrogen in the soil readily available to the plants. The growth contributed by nitrogen may have provided the pathogen with readily available substrate. As reported by Marchner (1995) that an increase in low molecular weight organic nitrogen compound as a substrate contributes to the high pathogen infection.

Plots applied with husk ash showed the least infection (Figure 1) indicating that the silicon present in the husk may have contributed to the low rice blast infection.
High infection of rice blast was also realized in the plots that had no nitrogen 0 KgN ha^{-1} (N0) and in 40 KgN (N1) which was a low application rate. Much as high nitrogen level increased rice blast infection, nitrogen deficiency is also detrimental and there is an optimal level required by the rice plant to enables it resist *Pyricularia oryzae* pathogen. These observations indicate that rice blast infection would occur if nitrogen is limiting or if applied in excess (Figure 1).

Plots with higher silicon rates (1000 and1500 KgSi ha^{-1}) showed that plants were moderately resistant to the pathogen indicating that silicon played a role in disease management probably through its deposition in the cell wall creating mechanical barrier to pathogen penetration. It was also likely that the erectness caused by the silicon allowed more light to the leaves preventing the

formation of large canopy hence un-conducive environment for the disease to thrive. Although it is not easy to establish the hypothesis with the prevailing data, there is a possibility that silicon triggers the rice plant cell defense mechanism such that by the time the appressoria penetrate the plant it hasphysiologically prepared its defenses. Since all plants produces phytoalexins against infection it is unclear on how silicon contributes to plant disease resistance. Further research is necessary.

Conclusion

The findings of this research indicate that rice blast disease can be managed through proper nutrition management. Nitrogen application at 120 Kg ha^{-1} led to high rice blast infection as well as in low (40 kgN ha^{-1}) application and where no (0 kgN ha^{-1}) nitrogen was applied. This brings to a conclusion that when nitrogen was deficient or applied below 80 kg/ha the plant resistance to rice blast was low. Since silicon managed the disease at 1000 and 1500 kgSi/ha and the two levels were not significantly different it would be reasonable to adopt a lower level. The interaction of silicon and nitrogen at 80KgN/ha, 1000 kgSi/ha (N2S2) may be adopted to manage the rice blast in Mwea irrigation scheme. The organic husk ash at 2 tons/ha may be useful in management of the disease since it played positive role in suppression of the disease. The husk ash performance was found to be as effective as those plots that had 120 kgN and 1000 KgSi/ha. It may therefore be used as an alternative source of silicate since it produced similar results as those produced by the commercial silicate. These husk have no other alternative use and hence farmers could make good savings inform of purchase of silicate fertilizer through the use of husks. Since the trial was conducted under screened house condition further work is recommended verifying these results under field conditions.

Reference

Anon, (1992). Diagnostic survey of Western Kenya rainfed rice in Africa. Proceeding of International Rice workshop at Lusaka Zambia.appressorium formation in Magnaporthe grisea. *FEMS Microbiol.Lett*. **115**, pp 71-75.

Awoderu,V. A.(1990). Yield loss attributed to neck rot rice caused by *Pyricularia oryzae* Car. In Cotu d Ivori. Tropical pest Management **36**, pp 394-396.

Datnoff, L. E., Snyder, G. H., and Korndorfer, G. H. (2001). Silicon in Agriculture. Elsevier Science. Amsterdam, The Netherlands. pp 403.

Datnoff, L. E., snyder. G. H. and Jones, D. B., (1990). Influence of calcium silicate slag and fungicides on brown spot and neck rot development and yield of rice. 1990 Rice growers Seminar, Belle Glade EREC Research Report EV-1990, **2**, pp 26-33.

FAO, (2004). International Year of Rice. Food and Agriculture Organization

Helms, R. S (1990). Rice Production Handbook. University of Arkansas Cooperative Extension Service. Misc. Publ. 192.

International Rice Research Institute (2002). *standard evaluation systems for rice*

Kurschner, E., Bonman, J. M., Garrity, D.P., Tamisin, M.M., Pabale, D. and Estrada, B. A. (1992). Effects of nitrogen timing and split application on blast disease on upland rice. *Plant Disease, St. Paul*, v.**76**, pp 384-389.

Matsuo, T. and Hoshikama, K. (1993). Science of the rice plant morphology. Food and Agriculture Policy Research Center, Tokyo.

Marschner, H. (1995): Mineral nutrition of higher plants. 2nd ed., Academic Press, pp. 436-460.

Pinnschmidt, H. O., Teng, P. S., Bonman, J. M. and Kranz, J. (1993). A new assessment key for leaf blast (Bl). *IRRN* **18**. Pp 45-146.

SAS (Statistical Analysis Systems Institute) (2001). SAS System for windows. Release 8.12,SAS Inst. Cary, NC, USA.

NUTRITIONAL EVALUATION OF MUTANTS AND SOMACLONAL VARIANTS OF SORGHUM (*SORGHUM BICOLOR* (L) MOENCH) IN KENYA

E. G. O. Omondi, M. N. Makobe, C. A. Onyango, L. G. Matasyoh, M. O. Imbuga and E. N. Kahangi
[1,2]Department of Botany, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[3]Department of Food Science and Technology, Jomo Kenyatta University of Agriculture and Technology, Nairobi
[4]Department of Biological Science, Chepkoilel University College, School of Science, Eldoret, Kenya
[5]Department of Biochemistry, Jomo Kenyatta University of Agriculture and Technology, Nairobi
[6]Department of Horticulture, Jomo Kenyatta University of Agriculture and Technology, Nairobi
E-mail: eomondi2008@gmail.com

Abstract
Several improved sorghum varieties are adapted to semi-arid and tropic environments. Selection of varieties meeting specific local food and industrial requirements from this great biodiversity is important for food security in Kenya and other developing countries. More than 7000 sorghum varieties have been identified hence, need for further characterization with respect to nutritional traits. *Sorghum bicolor* (L) Moench mutants and somaclone lines (Seredo, Serena, Mtama 1 and El-gardam) were developed towards improvement for drought tolerance at the Jomo Kenyatta University of Agriculture and Technology. Using mutation techniques. X-ray with the dose of 15000R was used to induce genetic variation. Somaclones were produced through somatic embryogenesis on Linsmaier and Skoog's (LS) media with 0.5 M concentration of Mannitol as an osmoticum to simulate drought conditions. The study was conducted to evaluate the chemical composition, B-vitamins, mineral profile, anti-nutrient content and levels of protein digestibility of somaclones, mutants and parents of the *Sorghum bicolor* (L) Moench local cultivar in Kenya (namely Mtama 1, Seredo, El Gardam and Serena). The proximate composition, B-vitamins, anti-nutrient contents and levels of protein digestibility of the flour from the cultivars were determined. The chemical components did not vary among and within varieties ($P \geq 0.05$). Serena and Seredo showed high levels of Anti-nutreint (phytates and Tannins) than Mtama 1 and El-dargam (tannin: 0.03-2.22%, Phytates: 124.3-374 mg/100 g) ($P \geq 0.05$). The somaclones and mutants of the sorghum cultivars except Mtama 1 were noted to have reduced quantities of tannin. Protein digestibility range, between 39.1%-88.4% and were low in Seredo and Serena than in Mtama 1 and El-gardam. No differences ($P \geq 0.05$) were observed among and within the treatments of the same varieties of the sorghum for proximate composition, B-vitamins and mineral compositions ($p < 0.05$). It was concluded that major variations among the varieties arose due to anti-nutrients. High anti-nutrient factors would affect the utilization of the Serena and Seredo varieties since these anti-nutrients reduced the availability other nutrients.

Key words: Varieties, mutants, somaclones, drought-tolerance, nutritional traits, anti-nutrients

1.0 Introduction

Sorghum (Sorghum bicolor L. Moench) is the fifth most important cereal crop in the world after wheat, rice, corn and barley (FAO, 2005). About 90% of the world's sorghum areas lie in the developing countries, mainly in Africa and Asia. This crop is primarily grown in poor areas subject to low rainfall and drought where other grains are unable to survive unless irrigation is available. The future of the sorghum economy is linked with its contribution to food security in Africa, income growth and poverty alleviation in Asia, and efficient use of water in drought-prone regions in much of the developed world.

The sorghum grain quality is affected by factors such as genotype, climate, soil type, and fertilization, among others, which can affect the chemical composition and the nutritive value (Ebadi *et al*., 2005). Starch is the main component of sorghum grain, followed by proteins, non-starch polysaccharides (NSP) and fat (BSTID-NRC, 1996). Its protein content is higher than that of corn although its nutritional protein quality is lower (Dowling et al., 2002). Moreover, high tannins content in sorghum bind to protein, carbohydrates, and minerals making these nutrients unavailable for digestion by the body. Reduction of the tannins levels is possible through decortication, fermentation, germination and chemical treatment according to Beta *et al*., 1999, Dicko *et al*., 2005 and Drina *et al.,* 1990. Sorghum also contains phenolic acids (McDonough *et al*., 1986). The objective of this study was to evaluate the chemical composition, mineral composition, B-vitamins and anti-nutrients (tannin and phytates) content of the parent *Sorghum bicolor* (L) Moench local cultivar in Kenya (namely Mtama 1, Seredo, El Gardam and Serena) compared to their somaclones and the mutants.

2.0 Methodology

Four cultivars of *Sorghum bicolor* (L) Moench seeds form two growing seasons (about 5 kg for each cultivar) were selected from Kenya Agricultural Research Institute (K.A.R.I.) Katumani, a semi arid region in Eastern province of Kenya. They were: Serena, Seredo, Mtama 1 and El-dargam. *Sorghum bicolor* (L) Moench mutants and somaclone lines (Seredo, Serena, Mtama 1 and El-gardam) were developed towards improvement for drought tolerance at the Jomo Kenyatta University of Agriculture and Technology. Mutants were produced by using mutation techniques. X-ray with the dose of 15000R was used to induce genetic variation. Somaclones were obtained through somatic embryogenesis on Linsmaier and Skoog's (LS) media with 0.5 M concentration of Mannitol as an osmoticum to simulate drought conditions (Makobe *et al*., 2006). Ground samples from the seeds from the two growing seasons were use for the food analysis experiment. Each experiment was carried out in duplicates per sample.

2.1 Proximate Analysis

Moisture, protein, carbohydrates, fat, ash and crude fibre were determined according to AOAC methods specification 950.46 (AOAC, 1995).

Tannins: This was done according to vanillin-hydrochloric acid method (Burns, 1963; Price *et al*., 1978).

2.2 Phytates

For phytate determination, HPLC analysis according to Camire and Clydesdale, (1982) was used. 50 mg of each sample being utilized. Extraction was carried out with 25 ml of 3% H_2SO_4 for 30 minutes on a shaker bath (German model KS 259 basic) at medium speed for 30 min at room temperature. The slurry was filtered through fast filter and rinsed using a fine jet stream from a squeeze bottle, with a small volume of extracting solvent. The filtrate was transferred to 50ml centrifuge tubes and placed in boiling water bath for 5 minutes before addition of 3 ml of a $FeCl_3$. The tubes were heated in boiling water bath to allow for the complete precipitation of the ferric phytate complex. Centrifugation was done at 2,500 rpm (Japan model H-2000C) for 10 min. and the supernatant

discarded. The precipitates were washed once with 30m distilled water, centrifuged and the supernatant discarded again. Three (3) ml of 1.5N NaOH and a few ml of distilled water were added to the contents of the tubes. The volume will then be brought to approximately 30 ml with distilled water and heated in boiling water bath for 30 minutes to precipitate the ferric hydroxide. The cooled samples were centrifuged and the supernatant transferred to 50ml volumetric flasks. The precipitate was then rinsed with 10 ml distilled water, centrifuged and the supernatant added to the contents of the volumetric flask.

Samples of 2 µl of the supernatant were injected into a HPLC (Shimazu model C-R7A plus) fitted with a 50377 RP-18 (5 µl) column Cat. at an oven temperature of 30°C and RID-6A detector model. A stock solution of the standard containing 10mg/ml of sodium phytate (inositol hexaphosphoric acid C_6H_6 $OPO_3Na_2)_6$ + H_2O) in distilled water was prepared. Serial dilutions were made for the preparation of the standard curve. Results of the phytate content were obtained as per the calculations of Vohra *et al.,* (1965).

2.4 Minerals

Five grams of sample were weighed in crucibles and transferred to hot plates in the fume hood chamber where they were charred to clear all the smoke from the carbonatious material before transferring them to the muffle furnace. The charred materials were then incinerated at 550ºC until they were reduced to white ashes. The ashes were cooled, 15 ml of 6N HCL was added to each of them in the crucibles before transferring them to 100 ml volumetric flasks. Distilled water was used to top them up to the mark before mineral analysis (AOAC, 1995). Atomic Absorption Flame Emission Spectrophotometer was used for the sodium metal residue analysis of the alkali treated samples (Model A A-6200, Shimadzu, Corp., Kyoto, Japan).

2.5 Protein Digestibility

Protein digestibility was done according to the method described by Mertz *et al*., (1984). This method involved determination of the protein content of sample before and after pepsin enzyme digestion.

The pepsin digestion involved weighing 0.2 g of ground sample that was passed through a 0.4mm screen and adding 35ml of 0.1 M phosphate buffer: pH 2 containing 1.5mg pepsin /ml. Incubation of the pepsin-sample mixture was done at 37ºC for 2hrs with continuous gentle shaking. The suspension was then centrifuged at 4800rpm, at temperatures of 4ºC for 20 min (Centrifuge Model H–2000C, Shimadzu Corp., Kyoto, Japan). The supernatant was discarded and the residue washed with 15ml of 0.1 M phosphate buffer: pH 7 followed by centrifugation as previously done. The supernatant was again discarded and the residue washed on Whatman's No. 3 filter paper in a Buchner funnel. The filter paper containing the undigested protein residue was folded, placed in a digestion tube and dried for 2 hrs at 80ºC.

A blank was prepared and treated in the same way but without the sample. Protein content was determined using AOAC, 1995 Method 928.08.
Calculation: Percentage protein digestibility = (A−B)/A
Where: A = % protein in the sample; and B = % protein factor after pepsin digest.

2.6 Group B-vitamins

A reversed-phase HPLC method by Ekinci and Kadakal (2005), modified from Cho *et al.,* (2000) was used. The sample treatment consisted of SPE with Sep-Pak C_{18} (500 mg) cartridges that enabled separation of water-soluble vitamins and removed most of the interfering components. 20 g of water were added to 5 g of the sample. The mixture was homogenized using a homogenizer at medium speed for 1min. The homogenized samples were centrifuged for 10min at 14 $\times$ 10^3g

(Centrifuge Model H–2000C Shimadzu Corp., Kyoto, Japan). The stationary phase preparation involved flushing with 10ml methanol and 10ml water (pH 4.2) to activate it. The homogenized and centrifuged samples were then loaded. The sample was eluted with 5 ml acidified water (pH 4.2) then 10ml methanol at a flow rate of 1ml min^{-1}. The eluent was collected in a bottle and evaporated to dryness. The residue was dissolved in mobile phase and then filtered through 0.45 μm pore size filters. Approximately 20 μl of samples was injected into the HPLC column. The column elute was monitored with a photodiode-array detector at 234nm for thiamine, 324 nm for pyridoxine, 282nm for folic acid, and 261nm for niacin.

The vitamins were analyzed in a HPLC (Model SCL-10A, Shimadzu Corp., Kyoto, Japan) using a column of inertsil ODS 5 μm 4.6 × 250 mm 5LI0101Z with 0.1 mol /L KH_2PO_4 (pH 7.0)–methanol, 90:10 mobile phase (filtered through 0.45μm membrane and degassed by sonication), flow rate of 0.5 ml/min, a photodiode-array detector (Model Waters 2996, Waters Corp., Mailford, USA), oven temp. of 25ºC, and a sample volume of 20 μl. Identification of compounds was achieved by comparing their retention times and UV spectra with those of standards stored in a data bank. Five different concentrations of each standard were used to prepare calibration plots for each vitamin. This was done by plotting concentration (μg/ml) against peak area (mAU). Their correlation coefficients were greater than 0.997 (Appendix III). Concentrations of the water-soluble vitamins were calculated from integrated areas of the sample and the corresponding standards.

Vitamin content (mg/g) = (y/b) × (dilution factor / weight of sample (g) × 1000)
Where y=is the y intercept of obtained from the standard curve of the vitamin in question, and b is the peak area of the injected sample.

2.7 Statistical Analysis

Each determination was carried out in duplicates on the basis of growth season and the figures averaged. Data was assessed by the analysis of variance (ANOVA) (Snedecor and Cochran, 1987). Duncan Multiple Range Test (DMRT) was used to separate the means. Significance was determined at $P < 0.05$.

3.0 Results and Discussion

3.1 Chemical Composition

The proximate composition of sorghum flour from the parents, somaclones and mutants are shown in Table 1.

Table 1: Proximate composition of the sample raw materials (mg/100g) of the sorghum varieties

	Nutrients					
Cultivars	Moisture%	Protein	Fat	Carbohydrates	Crude fibre	Ash
El-gar. M	6.3^{bcde}±0.8	15.7^{a}±0.6	3.1^{ce}±0.2	70.2^{a}±0.14	3.1^{a}±0.11	2.7^{a}±0.1
El-gar. P	8.3^{ace}±0.1	13.8^{a}±0.4	3.8^{ace}±0.3	68.0^{a}±0.6	3.8^{a}±0.12	2.3^{a}±0.2
El-gar. S	6.4^{bcde}±0.4	16.8^{a}±0.4	2.6^{e}±0.2	69.4^{a}±0.1	2.8^{a}±0.48	2.1^{a}±0.5
Mta. 1 P	7.2^{abce}±0.1	12.9^{a}±0.2	1.4^{b}±0.5	73.4^{a}±0.44	3^{a}±0.42	3.6^{a}±0.6
Mta. 1 S	6.9^{abcde}±0.1	15.3^{a}±0.8	1.7^{b}±0.2	71.3^{a}±0.17	3.1^{a}±0.14	1.8^{a}±0.1
Mta. 1 M	6^{bcde}±0.1	12.8^{a}±0.6	3.2^{ce}±0	73.4^{a}±0.44	2.1^{a}±0.5	2.6^{a}±0.14
Seredo M	5.1^{bd}±0.5	15.1^{a}±0.6	3.0^{e}±0.4	72.9^{a}±0.19	2.4^{a}±0.33	1.9^{a}±0.04
Seredo P	6.4b^{cde}±0.2	13.3^{a}±0.6	4.6^{a}±0.4	71.8^{a}±0.72	2.6^{a}±0.21	1.5^{a}±0.3
Seredo S	7.7^{abce}±0.4	12.7^{a}±0.3	5.5^{ad}±0.2	72.5^{a}±0.41	2.2^{a}±0.36	2.1^{a}±0.12
Serena M	5.1^{bd}±0.3	15.8^{a}±0.2	5.9^{d}±0.1	68.4^{a}±0.34	5.9^{a}±0.23	2.6^{a}±0.03
Serena P	5.1^{bd}±0.3	14.4^{a}±0.5	4.7^{a}±0.07	70.7^{a}±0.76	3.1^{a}±0.5	2.0^{a}±0.33
LSD	0.03	0.07	0.03	0.08	0.01	0.05
C.V%	7.3	7.4	14.3	1.7	1.2	32.3

Values are means (± SD). Means sharing a common superscript letter in a column are not significantly different at ($p \leq 0.05$) as assessed by Duncan's multiple range tests. S.D=Standard deviation. LSD= Least significant difference of the mean replicates.

The ash content was found to range between 1.5% and 3.6% Mtama 1 parent being the highest and Seredo parent showing the lowest. The data obtained showed that the ash content of the cultivars do not vary significantly. The protein content was found to be in the range of 12.7% to 16.8% and do not vary among the cultivars with the different treatments. Protein content and composition varies due to genotype, and water availability, temperature, soil fertility and environmental conditions during grain development. The protein content of sorghum is usually 11-13% but sometimes higher values are reported. The fat content of the flour range between 1.4% and 5.9%. Fat content do not range widely between the cultivars but is noted to be significantly different between treatments of the same cultivar. Moisture content range 5.1% to 8.3% and do not vary significantly within cultivar treatments except in Seredo where the somaclone shows a higher moisture content than the parent and mutant. Carbohydrates content ranged from 68% to 73.4% and do not vary significantly within same cultivars and within treatments of the same cultivar. Crude fibre content ranged from 2.9% to 5.9% and do not significantly differ within and among cultivars.

3.2 Mineral Composition

Mineral composition of the sorghum cultivars are shown in Table 2. The ranges obtained are confirmed in previous similar work (Noha *et al.*, 2001). The mineral compositions among all the cultivars do not seem to vary significantly except for iron and calcium. Magnesium was found to range between 0.61-2.29 mg/100 g, Mtama 1 somaclone having the lowest with Mtama 1 parent being the highest. The lower amount of magnesium averagely in Seredo and Serena may be due to the fact that divalent cations such as Mg may be present as mineral phytate chelates which may explain the lower availability of these minerals (Mamiro et al., 2001). Copper ranged between 1.08-2.17 mg/100 g, zinc 0.12-0.44 mg/100 g, sodium 0.09-0.3 mg/100 g, calcium 2.45-3.52 mg/100 g, potassium 1.07-4.71 mg/100 g and iron 1.03-9.1mg/100g.

Table 2: Minerals composition (mg/100g) of the sorghum varieties

Cultivars	Mg	Mn	Cu	Zn	Na	Fe	Ca	K
El-Gar M	2.27^{a}±1.1	1.33^{a}±0.3	1.28^{a}±1.1	0.32^{a}±0.2	0.21^{a}±0.1	4.18^{b}±17.1	2.45^{e}±5.3	1.35^{a}±1.9
El-Gar P	2.02^{a}±0.6	0.58^{abc}±0.2	1.35^{a}±0.2	0.12^{b}±0	0.15^{a}±0.1	1.61^{f}±9.1	2.75^{cd}±6.3	4.70^{a}±1.8
El-Gar S	1.22^{a}±0.6	0.85^{abc}±0.1	2.09^{a}±0.8	0.16^{ab}±0	0.11^{a}±0	4.08^{b}±4.2	3.52^{a}±5.9	3.22^{a}±1.4
Mta. 1 M	0.70^{a}±0.1	0.67^{abc}±0.1	1.59^{a}±0.9	0.36^{ab}±0.1	0.30^{a}±0.2	0.91^{g}±4.2	2.52^{de}±12.5	5.01^{a}±2.8
Mta. 1 P	2.29^{a}±2.7	0.80^{abc}±0.6	1.24^{a}±1	0.30^{ab}±0.1	0.27^{a}±0.2	5.93^{a}±4.2	2.89^{c}±7.9	2.43^{a}±2.8
Mta. 1 S	0.61^{a}±0.3	0.61^{abc}±0.3	2.07^{a}±0	0.16^{ab}±0.1	0.29^{a}±0.1	3.39^{c}±6.1	2.49^{e}±11.8	1.99^{a}±0.4
Seredo M	1.19^{a}±0.2	1.19^{ab}±0.2	2.17^{a}±0.5	0.26^{ab}±0.2	0.13^{a}±0	1.07^{g}±0.35	2.94^{bc}±5.9	1.07^{a}±1.5
Seredo P	1.24^{a}±1	0.28^{c}±0.4	1.08^{a}±0.9	0.21^{a}±0.2	0.16^{a}±0	2.80^{c}±0.0	2.91^{c}±21.2	1.68^{a}±0.7
Seredo S	1.66^{a}±2	0.12^{c}±0.2	1.31^{a}±0.5	0.29^{ab}±0.2	0.16^{a}±0	1.03^{g}±0.98	2.83^{c}±11.9	2.22^{a}±1.1
Serena M	1.04^{a}±0	0.83^{abc}±0.3	1.76^{a}±0.5	0.21^{ab}±0.1	0.14^{a}±0.1	2.71^{d}±9.7	2.55^{de}±11.8	2.68^{a}±0
Serena P	1.47^{a}±0.9	0.42b^{c}±0.6	1.91^{a}±1.1	0.44^{a}±0	0.09^{a}±0.1	1.98^{e}±7.1	3.16^{b}±2.61	4.71^{a}±0
LSD	0.076	0.014	0.048	0.007	0.0069	0.048	0.067	0.093
CV%	82.5	32.2	46.4	43.5	59.7	28.1	37.2	49

Values are means (± SD). Means sharing a common superscript letter in a column are not significantly different at ($p \leq 0.05$) as assessed by Duncan's multiple range tests. S.D=Standard deviation. LSD= Least significant difference of the mean replicates. S=somaclone, P=parent, M=mutant

3.3 Group B-Vitamins

The vitamins results are shown in (Table 3) and are in the ranges obtained by Mamoudou *et al*, 2006. Niacin ranged between 0.2-6.65mg/100g. Seredo mutant showed the lowest while Mtama 1 had the highest quantities. There were no significant differences in niacin quantities among all the cultivars and within each cultivar. Thiamine quantities ranged between 0.1-1.49 mg/100g with El-dargam parent showing the highest and Seredo mutant having the lowest. There are no significant differences among all cultivars and within each cultivar. Vitamins are reported to be unstable and can be lost during processing and storage (Ekinci and Kadakal, 2005)

Table 3: B-vitamins in of the sorghum varieties

Cultivars	Niacin	Thiamin	Riboflavin	Pyridoxine
El-gar M	0.91^{de}±0.0	0.16^{c}±0.0	1.37^{de}±0.24	0.22^{b}±0.0
El-gar P	1.19^{cd}±0.3	1.49^{a}±0.6	0.29^{f}±0.06	0.48^{b}±0.1
El-gar S	1.05^{d}±0.2	0.43^{bc}±0.0	6.0^{a}±0.2	0.15^{b}±0.0
Mta. 1 M	0.64^{de}±0.1	0.24^{bc}±0.1	5.93^{a}±0.26	0.16^{b}±0.0
Mta. 1 P	6.65^{a}±0.1	0.14^{c}±0.0	3.33^{b}±0.07	0.16^{b}±0.0
Mta. 1 S	0.75^{de}±0.1	0.22^{bc}±0.0	1.39^{de}±0.27	0.03^{b}±0.02
Seredo M	0.2^{e}±0.0	0.1^{c}±0.1	1.33^{de}±0.0	0.73^{b}±0.06
Seredo S	0.85^{de}±0.8	0.35^{bc}±0.1	2.26^{cd}±0.5	0.65^{b}±0.14
Seredo P	0.66^{de}±0.4	0.19^{bc}±0.1	2.99^{bc}±0.01	0.25^{b}±0.02
Serena M	2.30^{b}±0.0	0.56^{bc}±0.1	6.44^{a}±1.2	0.14^{b}±0.03
Serena P	1.82^{bc}±0.2	0.65^{b}±0.0	0.61^{ef}±0.02	0.07^{b}±0.01
LSD	19.3	47.1	14.4	53
C.V%	0.02	0.01	0.03	0.03

Values are means (± SD). Means sharing a common superscript letter in a column are not significantly different at ($p \leq 0.05$) as assessed by Duncan's multiple range tests. S.D=Standard deviation. LSD= Least significant difference of the mean replicates. S = somaclone, P = parent, M = mutant

3.4 Anti-nutrients

The anti-nutrients results for the sorghum varieties are shown on (Table 4). The tannin values were similar to those reported from similar studies (Gomez *et al*., 1997; Beta *et al*., 1999).

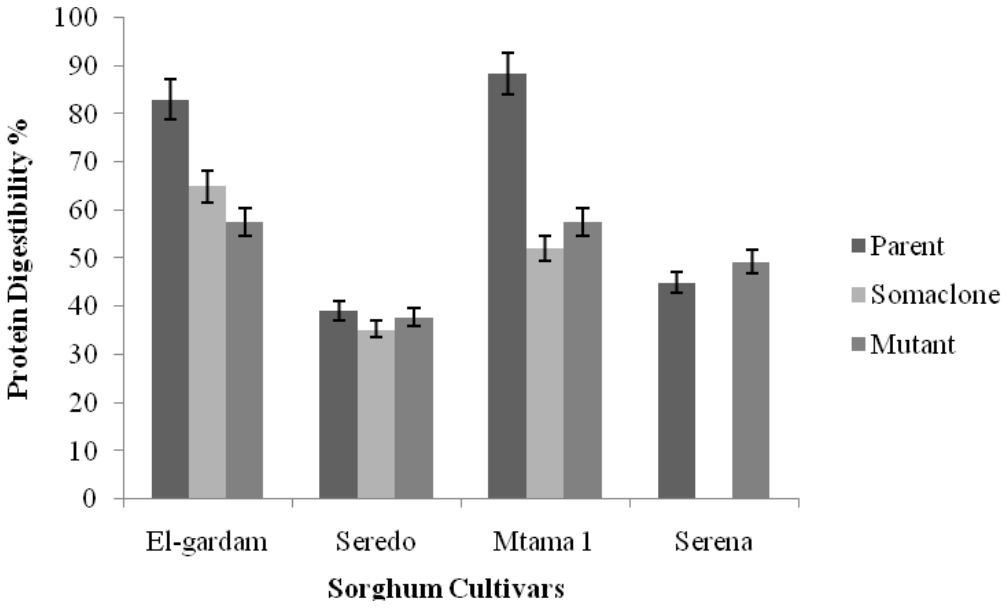
Table 3: Anti-nutrient factors (Tannins and phytates) in the sorghum varieties

Cultivars	Tannins (%C.E)	Phytates (mg/100g)
El-gar M	0.12^{b}±0.03	250.3^{e}±11.7
El-gar P	0.81^{ab}±0.06	288.9^{d}±9
El-gar S	0.70^{ab}±0.04	254.9^{e}±3.8
Mta. 1 M	0.06^{b}±0.04	255.6^{e}±5.9
Mta. 1 P	0.03^{b}±0.01	170.0^{f}±0.99
Mta. 1 S	0.04^{b}±0.01	124.3^{g}±5.2
Seredo M	0.49^{b}±0.08	295.1^{d}±1
Seredo S	0.88^{ab}±0.2	320.5^{c}±13.3
Seredo P	2.22^{a}±0.06	351.4^{b}±2.6
Serena M	0.7^{ab}±0.03	374.5^{a}±5.9
Serena P	1.2^{ab}±0.16	155.0^{f}±2.8
LSD	0.04	0.44
C.V%	15.9	2.7

Values are means (± SD). Means sharing a common superscript letter in a column are not significantly different at ($p \leq 0.05$) as assessed by Duncan's multiple range tests. S.D=Standard deviation. LSD= Least significant difference of the mean replicates. S=somaclone, P=parent, M=mutant

Tannin content is generally realized highest in the red sorghum cultivars (Serena and Seredo) and lowest in the white sorghum (Mtama 1 and El-gardam). The range obtained (120-370%C.E) lies similar to ranges obtained in similar studies (Noha *et al*., 2001). The somaclones and mutants of the sorghum cultivars except Mtama 1 are noted to have reduced quantities of tannin. Red sorghum genetically has higher condensed tannin compared to white sorghum and pearl millet. Tannins impart a bitter taste to the grains making them unpalatable and also interfere with protein digestibility. Before ripening the tannin content of grain is always higher than after ripening. The tannin content of dark grains is always higher than that of pale grains. The phytate amounts are also noted to be elevated in the red sorghum generally compared to the white sorghum and ranges from 124.3% to 374.5%. Significant differences in the phytate quantities were observed within and among the cultivars.

Protein digestibility findings showed a range of 5.2% to 11.4% (Figure 1). The lower ranges for protein digestibility were noted in the red sorghum cultivars (Serena and Seredo) and higher for the white sorghum Mtama 1 and El-gardam). This can be attributed to the high anti-nutrient content in the red sorghum that reduces digestibility of proteins and utilization of other mineral contents in sorghum. In vitro studies and in vivo studies with livestock and laboratory animals indicate that sorghum proteins are generally less digestible than those of other cereals (Muindu and Thomke, 1981). Phytates and polyphenols such as tannins bind to both exogenous and endogenous proteins including enzymes of the digestive tract, affecting the utilization of proteins (Asquith and Butler, 1986; Griffiths, 1985; Eggum and Christensen, 1975).



Graph 1: Protein digestibility (%) of the sorghum cultivars

4.0 Conclusion

The insignificant mean square values obtained from the analysis of variance for the proximate composition, B-vitamins and minerals (Table 1) suggests that differences do not exist between the sorghum cultivars and between treatments of the same cultivars, indicating that they are not highly variable. Variability of the cultivars, however, is shown in the anti-nutrient content of the cultivars with Seredo, Serena and El-gardam showing elevated amounts. The white Mtama 1 especially, somaclone with lower anti-nutrient is therefore the best with respect to nutrient availability since anti-nutrients in sorghum are shown to reduce the utilization of nutrient by the body. However, methods such as fermentation, germination and fortification can be used to reduce anti-nutrients in those cultivars with high amounts.

Reference

AOAC, (1995). Official methods of analysis of AOAC internationa*l*. In: Ralph H. N (Eds).Cereal foods. AOAC international suite 500,481 North Fredrick Avenue, Guithresburg, Maryland 20877-2417 USA. Vol. **2**. 16th Edition, pp 1-43.

Asquith, T. N. and Butler, L. C. (1986). Interaction of condensed tannins with selected proteins. *Phytochem*., **25**, pp 1591-1593.

Beta, T., Rooney, L. W., Marovatsanga, L. T. and Taylor, J. R. N. (1999). Phenolic compounds and kernel characteristics of Zimbabwean Sorghums. *J. Sci. Food Agric.* **79**, pp 1003-1010.

Burns, R.E. (1963). Methods of tannin analysis for forage crop evaluation*. Georgia. Agricultural experiment station technical bulletin,* **32**, pp 1-14.

BSTID-NRC (Board on Science and Technology for International Development-National Research Council) (1996). Lost crops of Africa. Academic Press, Washington DC, pp. 127-213

Camire, A. L. and Clydesdale, M. (1982). Analysis of phytic acid in food by HPLC. *J. Food science*, **47**, pp 576.

Cho, C. M., Ko, J. H. and Cheong, W. J. (2000). The effect of fermentation and drying on the water-soluble vitamin content of *tahara,* a traditional Turkish food. *Talanta*. **51**, pp 799.

Dicko, M. H., Gruppen H. Traore A. S., Van Berkel W. J. H. and Voragen A. G. J. (2005). Evaluation of the effect of germination on phenolic compounds and antioxidant activities in sorghum varieties. *J. Agri. And Food Chem*., **53**, pp 2581-2588.

Dowling. L. F., C. Arndt and B. R. Hamker. (2002). Economic viability of high digestibility sorghum as food for market broiler*. Agronomy J*. **94**, pp 1050-1058.

Drinah, B. C. Banda N. and Pran V. (1990). Nutritional Improvement of Tannin-Containing Sorghums *(Sorghum bicolor)* by Sodium Bicarbonate. *Cereal Chem*. **67**(6), pp 533-537.

Ebadi, M. R., J. Pourreza, J. Jamalia, M. A. Edris, A. H. Samie and S. A. Mirhadi. (2005). Amin acid content and availability in low, medium and high tannin sorghum in grain for poultry. *Int. J. Poult. Sci.,* **1**, pp 27-31.

Eggum, B. O. and Christensen, K. D. (1975). Influence of tannin on protein utilization in feedstuffs with special reference to barley. In-breeding for seed protein improvement using nuclear techniques p. 135-143. (IDRC), International Agency of Atomic Energy.

Ekinci, R. and Kadakal, C. (2005). Determination of seven water–soluble vitamins in Tahara, a traditional Turkish cereal food, by high-performance liquid chromatography. *ACTA chromatographica*. No. 15.

Food and Agricultural Organization (FAO) (2005). FAOSTAT.
http://faostat.fao.org/faostat/

Griffths, D. W. (1985). The inhibition of digestive enzymes by polyphenolic compounds. *Exp. Biol. Med*. **199**, pp 504-516.

Gomez, M. I., Obilana, A. B., Martin, D. F., Madhvamuse, M. and Monyo, E. S. (1997). Manuals of Laboratory Procedures for Quality Evaluation of Sorghum and Pearl millet. Technical manual No. 2. Patancheru, Andhra Pradesh, India.

Makobe, M. N., Kahangi, E. M., Misra, A. K. and Imbuga, M. O. (2006). Development of Hardy Sorghum Cultivars for the Arid and Semi arid Regions*. African Crop Science Journal*, **14**(4), pp 297-309.

Mamiro, P. R. S. Vancamp, J. Mwikya, S. M. and Huyghebaert, A. (2001). In vitro extractability of calcium, iron and zinc in finger millet and kidney beans during processing. *J. Food Sci*. **66**, 1271-1275. *International Journal of Biological and Life Science,* **6**(1), pp 2010 39

Mamoudou H. Dicko, Harry Gruppen, Alfred S. Traoré, Alphons G. J. Voragen and Willem J. H. van Berkel. (2006). Sorghum grain as human food in Africa: relevance of content of starch and amylase activities. *African Journal of Biotechnology*, **5** (5), pp 384-395.

McDonough, C. M., Rooney L. W. and Earp, C. F., (1986). Structural characteristics of Leucine Coracana (finger millet) using scanning electron and fluorescence microscopy. *Food Microstructure*, **5,** pp 247-256.

Mertz, E. T., John, D. A., Kirleis, A. W., Hassen, M. M., Nora, D. M., and Lars, M. (1984). Digestibility of sorghum proteins .Proc. NatL Acad. Sci. USA. *Applied Biology,* **78**(3), pp 1333-1335.

Muindi, P. J., and Thomke, S. (1981). The nutritive value for rats of high- and low-tannin sorghums treated with Magadi soda. *J. Sci. Food Agric*., **32**, pp 139.

Noha A. Mohammed, Isam A. Mohamed Ahmed and Elfadil E. Babiker. (2001). Nutritional Evaluation of Sorghum Flour (*Sorghum bicolor L. Moench)* During Processing of Injera. *International Journal of Biological and Life Sciences,* **6**(1) 2010.

Price, M. L., Van Scoyoc, S. W. and Butler, L. G. (1978). A critical evaluation of the vanillin reactions as an essay for tannin in sorghum grain. *Journal of Agric. Food Chem.*,**26**, pp 1214-1218.

Snedecor, G.W. and Cochran, W. G., (1987). Statistical methods (17th Ed.) Ames, IA: The Iowa state University Press.

Vohra, P., Gray, G. A. and Kratzer, F. H. (1965). Phytic acid-metal complexes. *Proc. Soc. Exp. Biol. Med*., **120**, pp 447–449.

NON – FOOD SWEETPOTATO PRODUCTS FOR INDUSTRIAL PRODUCTION AT UNIVERSITY OF EASTERN AFRICA, BARATON

F. L. Mkandawire, D. Kebaki, A. Poblete, N. Angwenyi, S. Mule and T. Muchee
University of Eastern Africa, Baraton, Eldoret, Kenya

Abstract
The main aim of the paper is to report some practical non-food processing strategies for sweetpotatoes under study at University of Eastern Africa, Baraton (UEAB) in order to exploit the immense potential of the sweet potato (*Ipomoea batatas*) for industrialization and development. Results demonstrate this crop has unrivaled potential for value addition along the production, processing, marketing and utilization chain. Apart from the usefulness of tubers and leaves as food for both livestock and human beings, dried vines can be bound into decorative panel boards. This novel usage of the sweet potato will particularly benefit subsistence farmers in sweet potato growing areas to add value to the sweet potato by utilizing an otherwise rejected material, the vines. This would in turn raise the livelihoods of farmers through generation of extra income. As such, the main beneficiary would be the resource challenged African women living in areas where sweet potatoes are grown in sub – Saharan Africa. There is an indication that decorative panels can be bound by any commercial glue or that made from sweet potatoes. Good panels are produced from dried mature vines chopped into 2 cm pieces carefully mixed with an adhesive to make sure that each chip is in contact with the glue. The materials were placed between an improvised presser made of metal sheets 20 x 20 x 2 cm in size, one at the bottom and the other on top. To prevent the material from sticking on to the board, a thin layer of polythene paper was spread on the upper side of the bottom plate as well as the lower side of the top plate. The mixture was placed, first from the corners, followed by the edges, then to the center. The metal plates were placed between two wooden blocks and pressed with a two – tone car jack for 30 minutes before it was removed and placed in the oven for slow drying at 80^0C for 48 hours. The resulting product is the appended panel which can be used for decoration, a picture frame and wall hanging.

Key words: Sweetpotato, vines, chips, panelboard, starch, jack, sweetpotato glue, urea formaldehyde

1.0 Introduction

Sweetpotato is grown by poor farmers mostly women in Western Kenya (Kakamega, Bungoma, Busia) and Nyanza (Homa Bay, Rachuonyo, Kisii and Nyamira) districts. It is also grown to a small extent at the coast and central province. The crop has many uses, although it is mainly grown for its tuber, which is used in many different ways as human food, as well as feed for livestock. The leaves are eaten as a vegetable by some communities, while fresh vines are chopped into small pieces and used as concentrate feed for livestock. Tubers are also processed into flour, which is blended with wheat flour. The flour is used in the manufacture of confectionery products like cookies, bread, biscuits and cakes. Leaves are made into juice and tablets which are rich in iron. In industry, the sweetpotato has been used in the manufacture of alcohol, methane and starch. Starch from sweetpotatoes has many applications in industry. These applications include manufacture of an adhesive, which acts as a binder. The advantage of the sweetpotato binder is that it is organic, environmentally friendly, and biodegradable over time. It is also important to note that sweetpotato growing areas are not conducive for livestock because of diseases and insect pests. As such, the use of vines for livestock feeding is limited and they are usually left to rot in the field and re-cycled back into the soil. The outer portion of vines when dry is high in cellulose and lignin, which can be used in industry and add value to an otherwise, rejected material. This would in turn raise the livelihoods of farmers through extra income generation. The main beneficially would be the poor African women living in Sub-Saharan Africa.

Over 75% of wooden panels, chipboards and furniture are currently made from wood. It is a common phenomena that as a result of increase in population in Kenya which is approaching 40 million mark, land is becoming smaller and smaller. This has resulted into the dwindling of forest resources because of gradual deforestation (NEEMA, 2004). Following the high rate of deforestation and scarcity of land in general, there is a likelihood of running short of raw materials for the timber industry. It is in this regard that there is need for research into alternative sources of basic raw materials for panel and chipboard production.

Conventionally, panel and chipboards are made from wood shavings, sawdust, wood chips and fibers generated from saw mills and other wood processing factories (Tinkelenberg *et al.*, 1982). Chipboard, sometimes referred to as particleboard, is essentially an inexpensive alternative to solid wood, and is used for interior paneling projects where appearance and durability is not a priority (Michael, 2009). In Kenya, panel and chipboards are made from remains of *Cupressus sempervirens* and *Pinus resinosa*. Urea formaldehyde, urea melamine formaldehyde resin and polyisocyanate are used as binding agents (Blumer, 1991). These substances emit toxic fumes, which are harmful to the environment (Steigninger, 1990).

Panel and chipboards are made in a variety of ways. According to Steigninger (1990), they are made by compressing, applying pressure and heat of 105 to 220^{0}C to wood chips that have been mixed with a resin binder. Kakuichi (2002) reported of the procedures of making three-layered 25 x 30 cm chipboards where chips are mixed in the ratio of 1:2 with the amount of resin content sprayed from a nozzle at a pressure of 2kg/cm^2 decreased from 11% on the surface to 7% in the centre and hot pressed between 150 and 155^{0}C. The amount of residual formaldehyde is an environmental concern. In this regard, Mayerhoffer (1981) came up with a method of reducing the content of solid resin binder through uniform curing of the binder over the entire board surface resulting into improved strength. Tinkelenberg *et al*. (1882) described another method of chipboard making where lignocelluloses chips are mixed with polyisocyanate and an aminoplast resin as bonding agent are hardened at a temperature of 150-200^{0}C and a pressure of 3.5N/mm^2. In this method, cellulose is sprayed with the resin solution

and spread on a suitable substrate while polyisocyanate is applied either mixed with the resin solution or separately before, during or after application of aminoplast resin.

Chipboards, although advantageous, have their own disadvantages in handling. Blumer (1991) reported that high-density chipboards are difficulty to handle and the cost of chips and glue used is high. High density result into chipboards of low moisture stability (Attwood, 1998. Conventional chipboards emit large quantities of formaldehyde into the air thus polluting the environment. According to Michael (2009), chipboards are hardy, weather proof, termite resistant, and strong. As such, waste wood material can be recycled into useful inexpensive products for the construction industry.

Currently, there is no documented report on the potential of sweet potato processing into panel and chipboard. It is against this background that this study was initiated to determine the use of sweet potato vines in the production of novel products. The main purpose of the study was to fulfill the following objectives: evaluate industrial uses of the sweet potato vines and process some novel products such as decorative panel boards made by following the same procedures like the ones for chipboard manufacturing process.

2.0 Materials and Methods

The experiment was carried out in the laboratory and it started with the extraction of starch from the sweetpotato roots. The roots were cleaned, peeled and grated before they were ground by a blender (AACC, 2000). After grinding, the homogenate was passed through an 80 mm sieve. After which, the residue was washed three times with refrigerated water. The slurry was then passed through a 200 mm sieve and left in water overnight at 5^0C for decantation. The precipitate was recovered by centrifuging at 1700 xg for 15 minutes. The decant was washed with Ethanol, and dried at 38^0C in an air circulated oven (Peroni *et al.,* 2006). The second method of starch extraction was done by grating the peeled sweetpotato tubers, and by using an improvised presser. Starch was obtained by pouring off the slurry and the sediments were dried. Glue was made by first boiling water to 100^0C, and measuring 200mls into a jug (Hoover, 2001). After that, 200g of starch powder was weighed and mixed with the measured boiled water, to make a suspension of starch water, which was stirred into a thick paste. The paste was then poured into boiling water slowly while mixing. A thick translucent paste was obtained of was the organic adhesive.

Vines were collected from a two-year fully-grown sweetpotato crop by cutting them from the base of the mother plant. Leaves together with the petiole and tender shoots were removed. The vines were dried under shade until brittle. Dried sweet potato vines were chopped into at least 2 cm lengths by using the forage chopper. The chopped dry vines were mixed with the adhesive produced from sweetpotato very carefully in a plastic container to make sure each chip was in contact with sweetpotato glue. An improvised presser was made from metallic sheets of high density with dimensional measurement of length, breadth and height of 20 x 20 x 2 cm, respectively. The presser had two metallic sheets, one on top and the other at the bottom during pressing. First, the bottom metallic sheet was put in place. This was followed by spreading a polythene paper foil, to prevent the mixture from sticking onto the presser. The mixture was placed, first from the corners, followed by the edges, then the center. After which, another roll of the polythene paper foil was spread on the mixture, before the top metallic lid, which was followed by a wooden block as a base for the two-tone car Jack. A pivot frame was joined onto the presser circumference frame, holding the two-tone car Jack in position once it was engaged, to exert pressure onto the top of the presser so as to provide pressure. The board was left under pressure for thirty minutes, before it was removed for drying in the oven at 80^0C for 48 hours.

3.0 Results and Discussion

The resultant products are panels illustrated in Appendix 1. These panels can be used for decoration and background for picture frames. Experiments are underway to design an effective pressing machine that can produce higher pressure to make the panel stronger.

This study has shown that sweetpotato vines can produce panels. Kakuichi (2002) stressed on a single hot pressing, which progressively raises the temperature in the lower layers of the chipboard. The same technique could be used for panel boards under controlled temperature. In this study pressing was done once and the product was taken for drying in the oven. It is likely that expansion might have taken place during drying since no pressure was used in the oven. This is in agreement with Steigninger (1990) who reported that heated fibers expand during initial compression because of ductility. A second heat pressing which was not done in this study could prevent this. The findings from the study also cagree with those of Kakuichi (2002) who showed that conventional chipboards that comprise of a centre layer of coarse wood chips and sandwiching outer layers of finer wood chips are characterized by high density.

4.0 Conclusion and Recommendation

The study has indicates that sweet potato vines bound by sweet potato starch can produce panel boards. This provides an income generation activity and has potential for poverty alleviation among poor women farmers of the Sub-saharan Africa. The use of starch as a binder will minimize the emission of formaldehyde from conventional chipboards into the atmosphere.

References

AACC (2000). Approved Methods of the American Association of Cereal Chemists. Saint Paul, MN: American Association of Cereal Chemists, pp 36-71.

Attwood, B.W. and Curry H.G. (1998). Production of fibrous sheet materials. US Free Patents No: 05/751038.

Blurner, H. (1991). US Freepatents on line. No: 07/566398. Stockhom, SE.

Hoover R. (2001). Composition, molecular structure, and physicochemical properties of tuber and root starches: A review. *Carbohydrate Polymers,* **45**, pp 253–267.

IPC (2000). International potato centre: Annual Progress Report. 07: 73.

Ruchetts, Frederick S, Merrit (2000). Building design and construction hand book. Mcgrawll New yolk, pp 75-76.

Josef, R. (2004). Potato starch extraction: Starch Technologies 21-22.

Kakuichi K. (2002). Stress Relaxation of chipboard in Hot-press: (Studies of on hardboards, No.20) University of Tokyo, pp 3-11.

KEFRI, (2003). Kenya Forestry Research Institute. Annual Report, 10:106.

Lindeboom, N., Chang P. R. and Tyler R. T. (2004). Analytical, biochemical and physicochemical aspects of starch granule size, small granule starches: A review. *Starch,* **56**, pp 89–99.

Mayerhoffer H. (1981). Wood chipboard and process preparation. US patent No: 4285843. (Vienna AT), 2.

Michael P. (2009). Manufacture of partial boards. Conjecture corporation, 1.

Moorthy S. N. (2002). Physicochemical and functional properties of tropical tuber starches: A review. *Starch,* **54**, pp 559–592.

Peroni F. H. G, Rocha T. S. and Franco C. M. L. (2006). Some structural and Physiological characteristics of tuber and root starches. *Journal of Food Science and Technology*, **12**, pp 505.

Steininger, H. P. (1990). Methods of the continuous production of chip, fiber and Similar boards. US patents No: 07/202140. Springe, DE.

Tinkelenberg A. Vaessen H. and Suen K. W. (1982). Manufacture of Chipboard US Patent No. 4362827

Appendix 1: Examples of panel boards made from sweet potato

INFLUENCE OF STORAGE TEMPERATURES ON THE POST-HARVEST QUALITY OF SNAP BEAN (*PHASEOLUS VULGARIS* L.)

J. N. Kinyuru[1], P. Kahenya[1], M. Muchui[2], H. Mungai[1], and M. Ithiga[1]

[1,2,4,5]Department of Food Science and Technology, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya

[3]Kenya Agricultural Research Institute, Thika, Kenya

E-mail: jkinyuru@gmail.com

Abstract

A preliminary study was conducted where mature snap beans of *Samantha* variety, were collected from small holder farmers in 2 growing seasons and data was collected with a view to developing a model for short term storage for prediction of the relationship between storage conditions, physical and nutritional quality under low density polythene bags. Half of the samples were packed separately in open polythene bags while the other half was packed in closed polythene bags and stored at 5^{o}C, 10^{o}C, 15^{o}C and 25^{o}C and observations made for 9 days. It was observed that the higher the temperature, the higher the weight loss although the loss was higher in open polythene bags in all the storage temperatures. Similar trends were also observed in the loss of chlorophyll in both samples with samples stored at 25^{o}C showing 5.5mg/L of chlorophyll content at day 9. There was a higher loss in total soluble solids in the samples stored in open polythene bags at 25^{o}C with the samples showing 5.3% by day 9. There was a slower loss of vitamin C in samples stored in closed bags; however, the samples stored at 25^{o}C for both treatments had the greatest loss by day 9. The results show that packaging in polythene bags has to be coupled with low temperature storage in order to receive a desirable shelf life.

Key words: Snap beans, storage temperatures, polythene bags, postharvest quality

1.0 Introduction

Snap bean (*Phaseolus vulgaris* L.) production has become increasingly important to the horticulture farming community and to the Kenyan community in general. It comes second to cut flowers in foreign exchange earners. In the year 2000, 26,672 tons of snap beans valued at KES 3.4 billion were exported mainly to the EU market and by 2004 snap bean export volume increased to 32,700 tons earning KES 5.5 billion (HCDA, 2000; 2004). Production is mainly by small to medium scale farmers and the enterprise creates on-farm employment opportunities for the rural community, especially youth and women. Snap beans are nutritionally rich in vitamin A, vitamin C, iron and calcium which can contribute significantly to mixed diets (Kelly and Scott, 1992).

Snap beans are categorized as a highly perishable vegetable and quickly deteriorate if not given proper temperature management. Quality of snap beans is related to cultivars and postharvest handling (Monda *et al*, 2005). Recent data has shown that consumption of fresh and frozen beans has been on the increase compared to canned beans. The call for proper handling and management from harvest at rural farms to export exists (Monda *et al,* 2003). The main importing countries are the UK, France and Germany among others.

In Kenya, there is a constant influx of new varieties through seed companies and produce exporters (Ndegwa, 2001; Ndungu, *et al.,* 2004). The local and export market for snap beans is dynamic and this has lead to introduction of new varieties to meet market demands. The introduction of new snap bean varieties requires evaluation of their post-harvest characteristics in order to ascertain optimum handling procedures. Snap bean varieties, R-1515, R-1516, R-1262, *Samantha, Julia, Amy*, *Lexus* and *Paulista* and the locally improved variety *Kutuless* (J12) were evaluated for growth parameters, yield components and yields (kg/ha) at KARI, Thika during long and short rains season in the year 2001. That study made recommendations for National performance trials for the varieties that were found to be distinctly superior to the existing commercial varieties (Ndegwa *et al*., 2001).

Snap bean (*Phaseolus vulgaris* L.) *Samantha* variety has been commercialized and has been grown in Kirinyaga District by the small holder farmers (Ndungu, *et al.,* 2004). It is a variety that is meant for fresh and frozen market although farmers also grow other varieties, e.g., variety *Julia* meant for canning. Small holder farmers have been practicing different handling techniques with a view to prolonging the shelf-life of the snap beans with little regard to the inherent quality characteristics. Low-density polythene bag packaging is being practiced at the farm level and therefore this research work was aimed at evaluating the post-harvest quality changes of Snap bean (*Phaseolus vulgaris* L.) variety *samantha* as influenced by temperature and low-density polythene bags packaging.

2.0 Materials and Methods

Mature fresh snap beans, *samantha* variety, were harvested from small holder farmers in two growing seasons, long rains season 2009 and short rains season 2009 in Kirinyaga District. At green pod maturity, the crop was harvested 3 times per week at one day intervals for 6 weeks. The pods were graded into the three standard categories defined by width of pod cross section (CS): extra fine (6 mm), fine (6-8mm) and Bobby (>8 mm) (KARI, 2005). The extra fine and fine categories comprised the marketable proportion of the harvest. Ten-pod samples of extra fine grade pods were selected randomly for assessment.

2.1 Chlorophyll Content

The content of chlorophyll was determined according to the method described by AOAC (1996). Four grams of the snap beans was weighed and ground in 16 ml of 100 % cold acetone; the homogenate was

filtered and the residue rewashed with 80 % cold acetone until all the homogenate was colourless. The extract was made up to 40 ml with 80 % cold acetone. Using 80 % cold acetone as the blank, an aliquot of the extract was taken and the absorbance measured at both 663 nm and 645 nm using a spectrophotometer (Model UV mini 1240, Kyoto, Shimadzu, Japan). Chlorophyll content was calculated using MacKinney's coefficients (Equation 1) after measuring absorbance (A) at 645 and 663 nm:

Total chlorophyll content (μg/g) = $20.2A_{645} + 8.02A_{663}$ .....(1)

2.2 Vitamin C (Ascorbic Acid) Content

The content of vitamin C was measured by visual titration using 2,6-dichlorophenol indophenol according to AOAC methods (1996). Five grams of the sample were weighed and ground in mortar and pestle with acid washed sand and some 10 % TCA solution. The ground sample was transferred quantitatively into a 100 ml volumetric flask, rinsed, made to the mark with 10 % TCA solution, mixed well and filtered. Ten (10) ml of the filtrate was titrated with indophenol solution until a pink colour appeared. For a blank, 10 ml of the 10 % TCA solution was pipetted in to a conical flask and distilled water equivalent to the volume of indophenol solution used in the titration was added. The mixture was titrated with indophenol solution until a pink colour appeared.

2.3 Total Soluble Solids

The total soluble solids was determined using an Atago hand refractometer (type 500, Atago, Tokyo, Japan). The results were expressed as degrees brix (°B).

2.4 Respiration Rates

The snap beans of a known weight were placed in jars of known volume whose covers were fitted with a self sealing rubber septum for gas sampling and incubated room temperature for one hour. One (1) ml of headspace gas was withdrawn using airtight syringe and injected into the gas chromatograph (GC) (model GC-8A, Shimadzu Corp., Kyoto, Japan). Carbon dioxide was determined using thermal conductivity detector with a Porapak Q column. Rate of carbon dioxide production were calculated as mg CO_2/ Kg/ hr at standard atmospheric pressure.

2.5 Weight Loss Determination

Samples of snap beans was packaged in both open and closed polythene bags at the start of the experiment and their initial weights noted. After each sampling interval, the weights were taken and the weight loss calculated as in equation 2:

$$\text{Weight loss} = \frac{\text{(Initial weight – Final weight)}}{\text{Initial weight}} * 100\ \% \quad \text{.....(2)}$$

2.6 Statistical Analysis

The statistical analyses of the results were mainly carried out by use of linear regressionWhere applicable, data were subjected to analysis of variance (ANOVA) using statistical application software (SAS) and means separated by the Student-Newman-Keuls (SNK) test.

3.0 Results and Discussion

3.1 Respiration Rate

The results of the respiration rates are shown in Figure 1. The rate of respiration generally increased with increase in storage period with the respiration rates being significantly higher ($p \leq 0.05$) after twelve days of storage. The respiration rates were also significantly higher ($p \leq 0.05$) in the open polythene bags as compared to the closed bags at all the sampling intervals. It was also noted that the respiration rate shot up on the ninth day but remained insignificantly different ($p \leq 0.05$) after the third

and sixth days. This indicates a major shift at the ninth day which indicates that it would be more prudent to store the snap beans for slightly less than nine days. This is in agreement with the studies carried out in USA which have indicated that the optimum storage period for the snap beans is 8 days.

The rate of respiration was also clearly affected by temperature, at each of the sampling periods, the rate of respiration was found to be significantly higher (($p \leq 0.05$) as the temperature was increased from 5°C to 25°C. it was also noted that the least increase in respiration rate was at 5°C. At 10°C, the rate of respiration was also low though significantly higher than at 5°C. It thus indicates that the best storage temperature would be 5°C and up to a maximum of 10°C. This is in agreement with the American study.

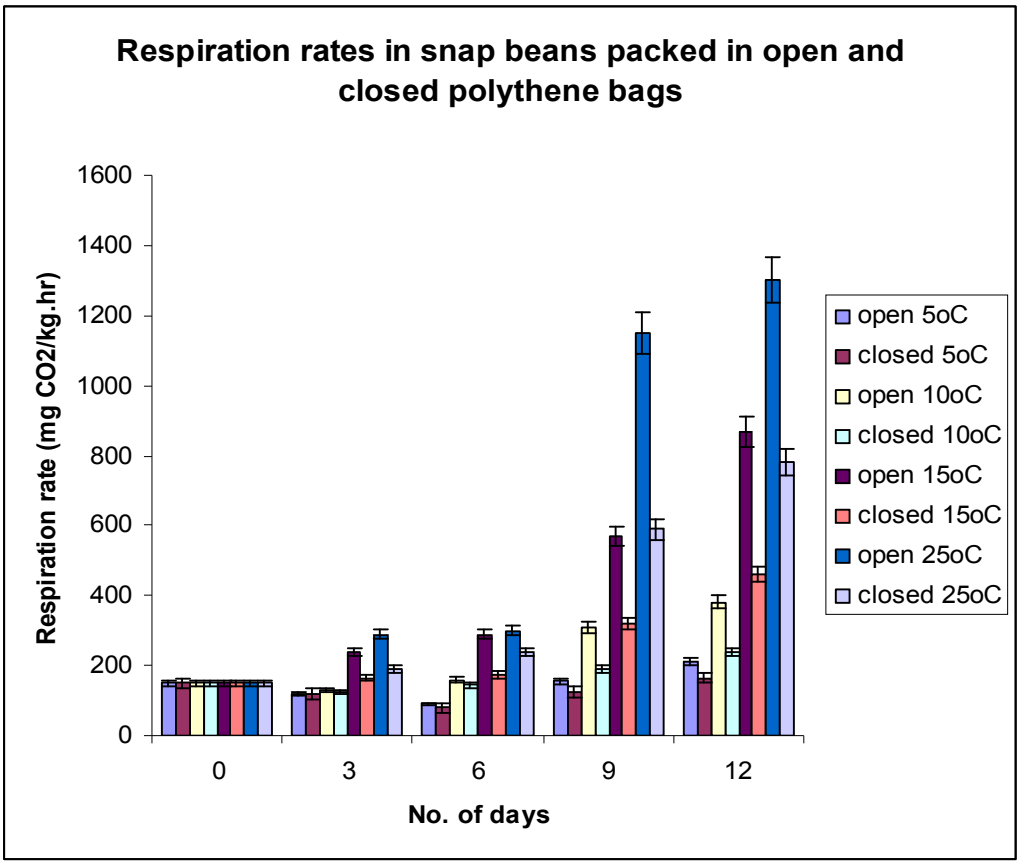


Figure 1: Respiration rate in snap beans packed in open polythene bags and closed polythene bags

It was also observed that the respiration rate was significantly lower ($p \leq 0.05$) in the closed polythene bags as compared to the open bags. The difference was even more marked at the higher temperature.

3.2 Weight Loss

The weight loss during the storage period is shown in Figure 2. The weight loss generally increased with the storage time. It was also noted to increase with increase in storage temperature. It was however noted that the increase was very low at 5°C. It was not significantly different ($p \leq 0.05$) between the sixth and twelfth days.

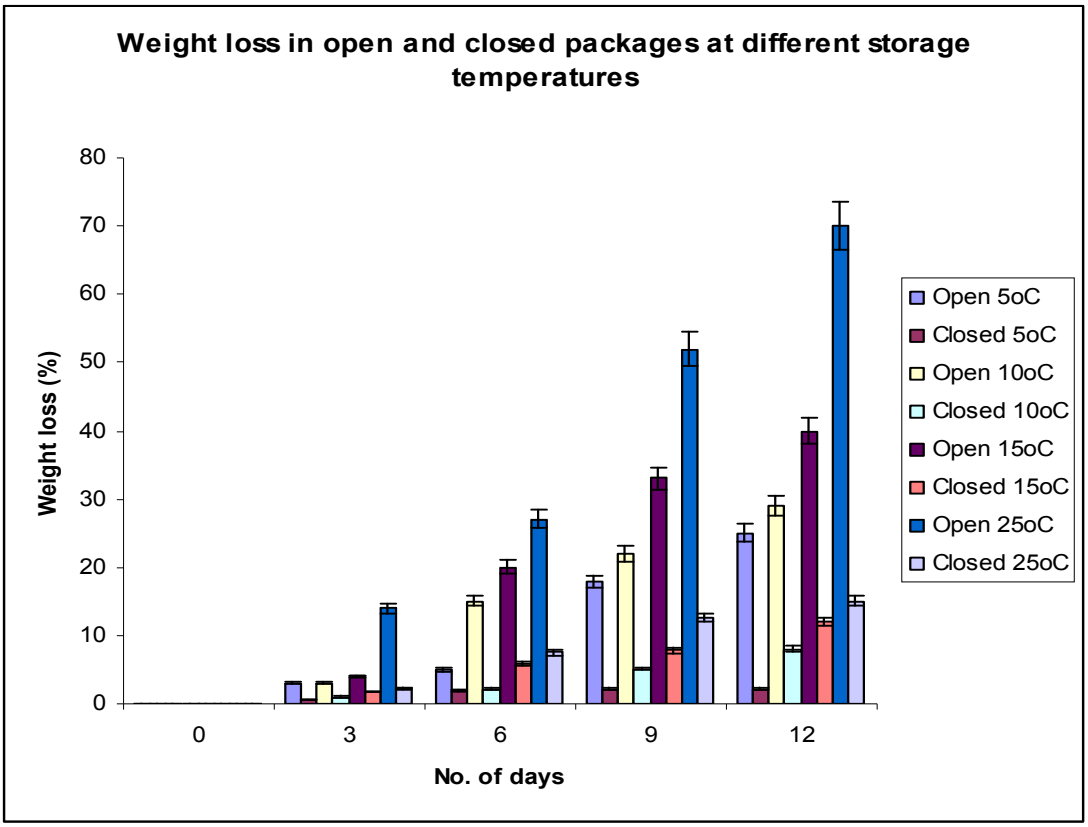


Figure 2: Weight loss (%) in snap beans packed in open polythene bags and closed polythene bags

At 10°C, the weight loss was quite low but significantly higher than at 5°C. It was also observed that the weight loss was significantly lower ($p \leq 0.05$) in the closed bags as compared to the open bags at all the temperatures and storage periods.

3.3 Chlorophyll Content

The results of chlorophyll content changes are shown in Figure 3. It was observed that there was a general decrease in chlorophyll content with increase in storage period. It was also noted that the decrease was more significant ($p \leq 0.05$) at the higher temperature. The decrease was lowest at 5°C where it remained almost constant for the entire period.

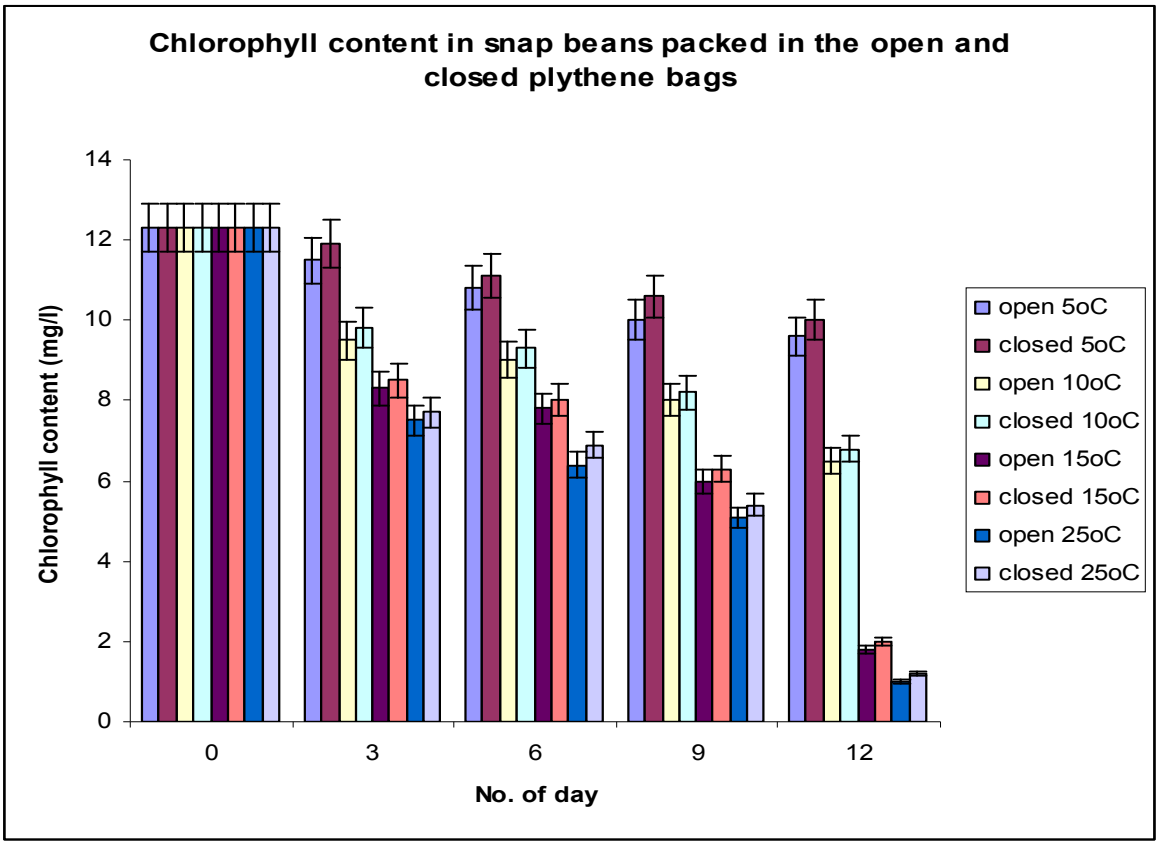


Figure 3: Change in chlorophyll content (mg/L) in snap beans packed in open polythene bags and closed polythene bags

The closed package was found to retain slightly more chlorophyll than the open packages though the greatest impact was due to both the storage temperature and period.

3.4 Total Soluble Solids

The results of total soluble solids are shown in Figure 4. There was a general decrease in total solids with the storage period. The loss was however significantly higher ($p \leq 0.05$) at both 15°C and 25°C. There were also significantly higher losses ($p \leq 0.05$) in the open packages than in the closed ones.

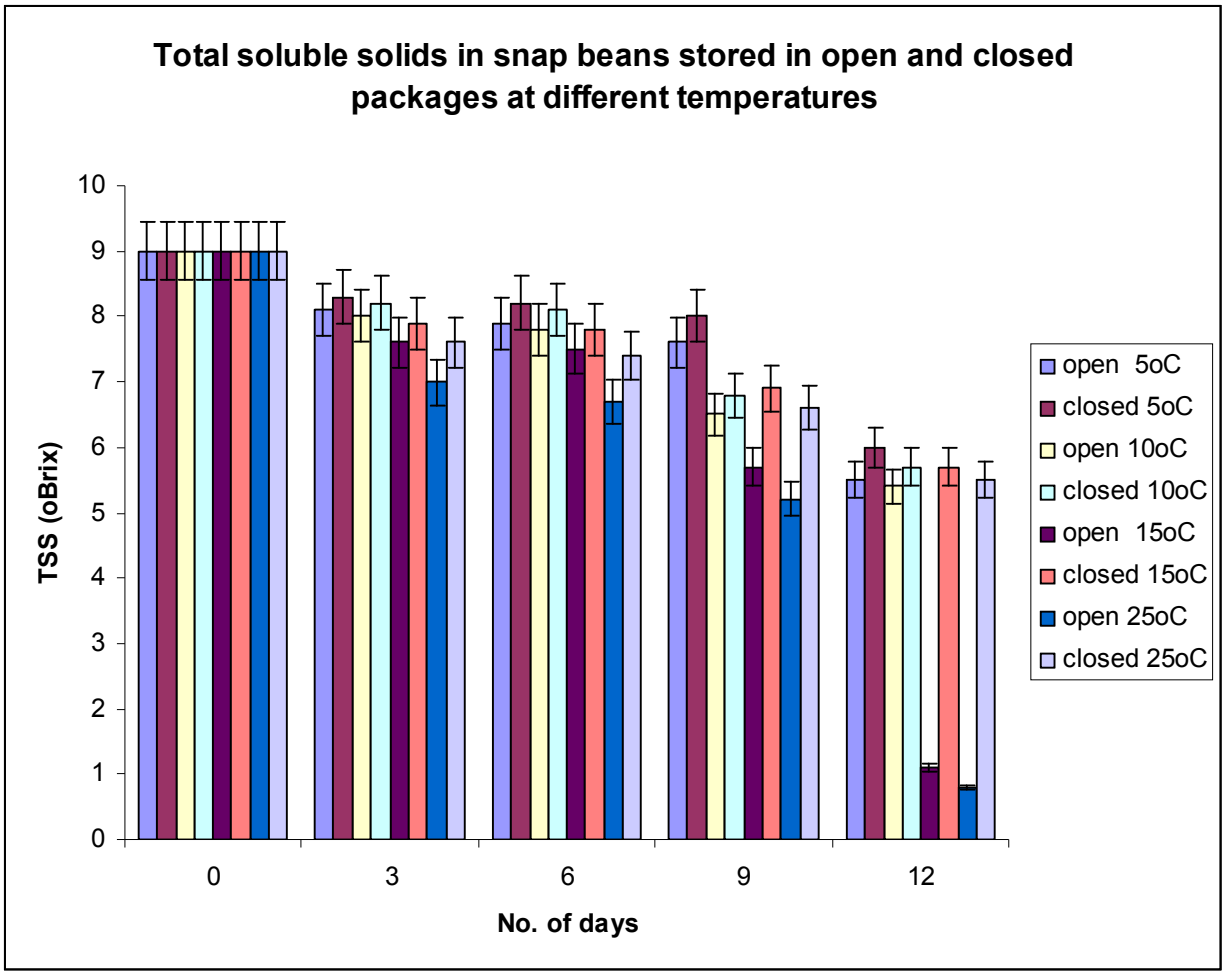


Figure 4: Total soluble solids (^{o}Brix) in snap beans packed in open polythene bags and closed polythene bags

3.5 Vitamin C Content

The results of vitamin C content are shown in Figure 5 below. Generally there was a reduction in vitamin C content with the storage period as similarly observed by Kaack (1994) The decrease was not significant within the first six days and especially for the lower storage temperatures. For both open and closed packages at 5°C, the vitamin C content remained almost constant.

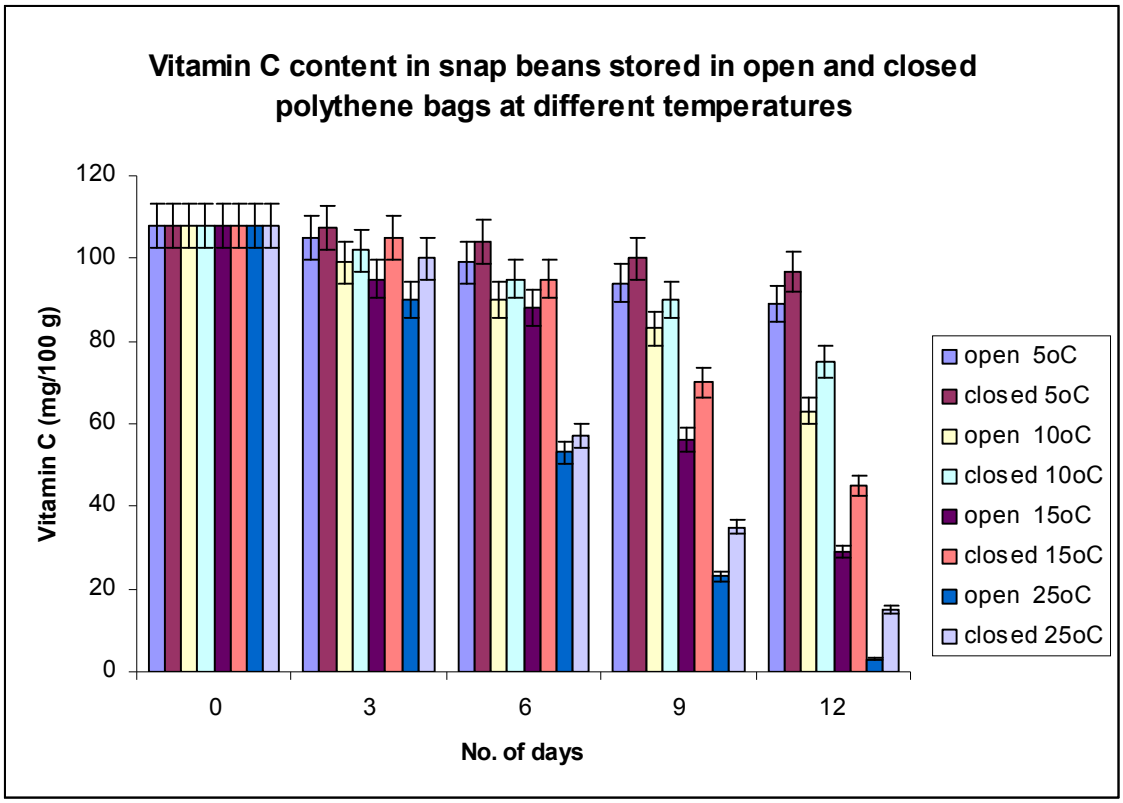


Figure 5: Change in Vitamin C content in snap beans packed in open polythene bags and closed polythene bags

Across the five parameters studied, it was observed that quality losses were lowest at 5°C and highest at 25°C. At 10°C, the losses were significant but reasonable. It can thus be suggested that the storage temperature of the snap beans should be at 5° or slightly higher than this to lower the energy consumption costs. A temperature of about 7°C would be ideal. The closed package was also found to significantly lower the rate of deterioration as assessed by the changes in the five parameters studied. A combination of both 5°C and closed package had the greatest preservation effect.

4.0 Conclusion

In conclusion a combination of low temperature storage and closed polythene packaging has a very good preservation effect on the quality of snap beans.

References

AOAC (1996). Association of Official Analytical Chemists. Official methods of analysis, 16th ed. Gaithersburg, Maryland.

HCDA (2004). Horticultural Crops Development Authority, Export statistics for Horticultural Crops in 2004.

Kaack K. (1994). Blanching of green bean (*Phaseolus vulgaris*). *Plant Foods for Human Nutrition,* **46**, pp 353-360.

KARI (2005). French (Snap) bean Production Manual. Revised Edition. KARI,Thika.

Kelly J. F. and Scott, M. K. (1992). The Nutritional Value of Snap Beans versus other Vegetables: In Proceedings of an International Conference held in Cali, Colombia, 16-20 October, 1989.

Monda E. O., Ndegwa A. M. and Ndungu B. W. (2005). Management of bean rust on French bean using Neem and Nettle extracts. Paper presented at AICAD Final Reports Workshop, Juja, Kenya.

Monda E. O., Ndegwa A. M., Munene S. (2003). French bean production in Nkuene and Abogeta Divisions of Meru Central District in Kenya. In Proceedings of 6th Biennial African Crop Science Conference. 12-17 October 2003, Nairobi, Kenya.

Muchui M. N., Ndegwa A. M., Njuguna L. W. (2001). Post-harvest Evaluation of Superior of Snap (French) Bean and Snow/Snap pea varieties. In Annual Report, KARI, Thika. pp. 111-112

Ndegwa A.M., Muchui M. N. (2001). Introduction and Evaluation of Snap and Runner Beans. In Annual Report, KARI, Thika. pp. 43-46

Ndungu B. W., Ndegwa A. M., Muchui M. N., Irambu E. M., Kambo C. M., Gatambia E. K. (2004). Baseline and Benchmark Report on Vegetable Production in Kirinyaga District of Kenya.

PERFORMANCE AND ECONOMIC EVALUATION OF PUMPED IRRIGATION SYSTEM: A CASE OF SMALLHOLDER HORTICULTURAL FARMERS

S. N. Kang'au[1], P. G. Home[2] and J. M. Gathenya[3]
Biomechanical and Environmental Engineering Department, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: staninjek@yahoo.com

Abstract
The study was carried out with the objectives evaluating the technical performance of the pumps used in smallholder irrigated agriculture, studying the energy uses during pumping and identifying the possible causes of inefficient energy use, and evaluating the costs of pumping used during irrigation. Observational study to identify occurrence of pumped irrigation systems in Kakuzi Division in Thika and Yatta Division in Yatta District was done. Semi structured questionnaires were administered to 80 respondents in the study areas to investigate the challenges of pumped irrigation as well as find the socio-economic status of the people and the agricultural practices carried out. A detailed study was carried out on 10 different pumps during irrigation to evaluate their efficiency as well as energy uses. The results showed that numerous challenges faced smallholder pumped irrigation systems some of which are irrigation component selection, design and operation as well as irrigation water management. 60% of the pumps evaluated operated below the recommended design efficiency. The pumps further showed different fuel consumption rates, while the cost of fuel used to irrigate an hectare of land varied for all the 10 pumps assessed. The lowest and highest fuel consuming pump used fuel valued at 350 ksh/ha and 8,426 ksh/ha, respectively. The huge difference is as a result of several factors such as pump consumption rate, farmer's irrigation timing among others. The result therefore means that some enterprises made huge profits while others operated at marginal profits or no profit at all. The results imply that without proper selection of the irrigation equipments, poor designs as well as lack of operational and management skills, the farming enterprises can be rendered uneconomical. This calls for embracing of the engineering, agronomic as well as management techniques at farm level in order to ensure sustainability of irrigated agriculture as well as enhance its economic viability.

Key words: Pump performance, economic evaluation, pumped irrigation, Kenya

1.0 Introduction

1.1 General

Irrigation is vitally important in meeting the food and fiber needs for a rapidly expanding world population (Terry, 2001). Investments in water for agriculture have made a positive contribution to rural livelihoods, food security and poverty reduction (Molden, 2007). During the second half of the 20th century, food production outpaced population growth, with some 78% of the production growth over the period 1961–1999 deriving from yield increases (Bruinsma, 2003) as opposed to agricultural land expansion. Higher yields have been achieved, in part, due to the expansion of irrigated areas and improvements in water management on irrigated lands. The area equipped with irrigation expanded from 139 million ha in 1961 to 277 million ha in 2003 (FAO, 2007).

In Kenya, irrigation development has been on the increase, particularly the smallholder irrigated agriculture.

Current estimates indicate that Kenya has a potential for irrigation of 540 000 ha (MOWRMD 2003). About 106 600 ha have been put under irrigation, comprising 20% of the potentially irrigable area. Large commercial farms cultivate 40% of irrigated land; government-managed schemes cover 18%, while smallholder individual and group schemes take up 42% of irrigated land (Republic of Kenya, 2004). Smallholder irrigated agriculture produces the bulk of local horticultural produce consumed in Kenya, as well as some export crops, and a substantial amount of dairy products. In the medium and high rainfall areas, supplementary irrigation based on surface flows has been instrumental in increasing productivity of high-value crops (Herdijk *et al*., 1990 and Mati, 2002). Due to the increase in irrigated area, numerous challenges facing smallholder farmers have emanated. The major constraints facing smallholder irrigation in Kenya include shortage of water as well as market availability, instability and unpredictability, both locally and abroad. In addition with over 80% of the smallholder irrigation schemes in Kenya being furrow-based, irrigation efficiency is very low hence the need for water saving techniques in the ASAL regions (Kibe *et al*., 2006). Further earlier estimates indicated that the irrigation efficiency for furrow based irrigation system hardly went beyond 40% with a loss that may exceed 60%. Moreover, research has shown that saving of water of between 30-40% can be achieved by using new irrigation methods.

Other challenges facing the smallholder farmers include the lack of a national irrigation policy, while inadequate investments have led to poor development of irrigation infrastructure and water storage facilities (Irrigation and Drainage Department, 2006). There is also inadequate technical capacity affecting farmers' organization and participation (Mati, 2008). Majority of smallholder farmers still rely on traditional methods of irrigation such as bucket irrigation systems which are most often inefficient in water use while most farmers do not irrigate their crops (Kibe *et al*., 2006).

It is due to the above findings that a study was commenced to study the performance of smallholder pumped irrigated agriculture and their economic performance.

2.0 Materials and Methods

2.1 Study Area

1.2.1 Location of the Study Area

Two study areas, i.e., Mitubiri location IN Kakuzi Division and Kithimani sublocation were chosen as the study sites where smallholder farmers practised pumped irrigation systems. Kakuzi division is located in Thika district of Central Province while Yatta division is located in Yatta district of Eastern province. Kakuzi division lies between longitudes of 36^0 40''w, 37^0, 21^0E and latitudes -1^0,20^0 N, -1^0,15^0S while

Yatta division lies between longitudes of -0.8^{0}W, -1.27^{0}E and latitudes of 36.66^{0}N, 37.10^{0}S. Kakuzi division is approximately 5 km and 52 km from Thika and Nairobi town respectively while Yatta division is 45 km and 81 km from Thika town and Nairobi town respectively. Kakuzi and Yatta division are on the north east and eastern direction from Nairobi town respectively. The location of the study area is presented in Figure 1.

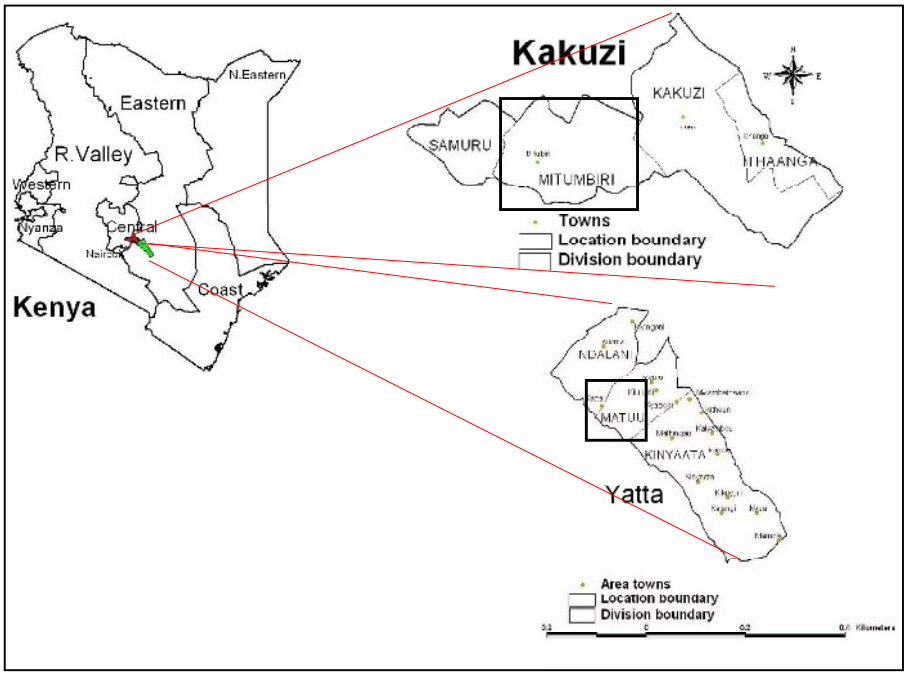


Figure 1: Location maps of Kakuzi and Yatta division with area towns and location boundaries

2.1.2 Population Density

The population density of Yatta division ranges from 152 Persons/km^2 (Frederick *et al*., 2000) while that of kakuzi division is approximately 71,622 persons and covers an area of about 481.2 Km^2 hence the population density is approximately 149 persons/ Km^2 (Robinson *et al*., 2005).

2.1.3 Water Sources

The available water sources in Yatta division are the Yatta furrow with its intake in Thika River at Mavoloni area. Yatta furrow plays a significant role in water supply to the residents of this area who practice both subsistence farming as well as horticultural farming for both local and export market. Its envisaged coverage was 60 kilometers but it covers an area of approximately 40 kilometers from the intake point due to water losses and misuse. The available water sources in Kakuzi division ranges from rivers, streams, springs and shallow wells. River Thika and Kabuku are the main water sources for the division since they are permanent while river Samuru is seasonal and highly polluted. Other springs such as Kasioni spring in Ithanga location is widely used by the residents.

2.1.4 Climatic Conditions

Rainfall patterns in parts of Eastern province exhibits distinct bimodal distribution. The first rains fall between mid-March and end of May and are locally known as the long rains (LR). The second rains, the short rains (SR), are received between mid October and end of December. Average seasonal rainfall is between 250-400 mm. Inter-seasonal rainfall variation is large with a coefficient of variation ranging

between 45-58 per cent, while temperature ranges between 17-24^{0}C. Evapo-transpiration rates are high and exceed the amount of rainfall most of the year except the month of November (Fredrick *et al*., 2000). Kakuzi Division rainfall distribution is bimodal with high peaks from March to May (long rains), and October to December (short rains). Annual rainfall varies from about 800 mm at an altitude of about 1525 m above sea level (ASL). The annual evapotranspiration increases from about 1250 mm at an altitude of 2400m ASL to about 1800mm at 1100m ASL (Gathenya, 1999). The temperatures are high at the lower altitudes ranging from 25^{o}C to 30^{o}C but reduce to between 18^{o}C and 20^{o}C towards the higher altitudes of 3500 m ASL. Mean annual evaporation which is 1485mm and 1625mm in Kakuzi and Yatta division respectively exceeds the rainfall (MOALD, 1998).

2.1.5 Agricultural Activities

Irrigated agriculture dominates the two areas due to unreliability of the rainfall. Few farmers practice subsistence agriculture during the short rain period and later on switch to irrigation. Only those farmers near the water sources benefit greatly as they practice supplemental irrigation to their crops. Pump fed agriculture is widely practiced by the residents in the two study areas.

2.2 Collection of Technical and Socio-Economic Data

Transect walks in the two study sites identified the agricultural activities of the farming community, the irrigation methods used as well as the socio-economic status of the people. Questionnaires were used to gather socio-economic data in the study areas. The questionnaire detailed the socio-economic status of the people, crops irrigated by the farming community, technical information such as irrigation methods used (water abstraction technologies, conveyance and application methods), irrigation equipments used i.e. pumps, pipes, hosepipes and other fittings and their selection procedure. The costs incurred during irrigation of horticultural crops were also identified through the questionnaire. A total of 80 farmers were interviewed, 50 in Kakuzi and 30 in Yatta Division.

2.3 Detailed Study of Pumping Units

Detailed study of the pumping units used in the study area was done. The make and model of 10 pumps was established and detailed evaluation of their efficiency, fuel use and power requirements during pumping was carried out. Economic evaluation of pumped irrigation systems was done and the overall seasonal energy cost computed.

2.3.1 Pump Working Efficiency

Pump efficiencies were calculated by first evaluating the pump specific speed from equation 1. In the equation, N_S is pump specific speed (rpm), N is pump speed (RPM) and is discharge (L/M.) and it is the total head (M). The pump speed was measured using a hand held tachometer at different levels of acceleration while the discharge and head were measured using a bucket and a quickset level respectively. The results of the calculations were read in the graph shown in Figure 2. The age of each pump was established through the questionnaire.

$$N_s = 0.2108N\left[\frac{Q^{0.5}}{H^{0.75}}\right] \quad \text{.....(1)}$$

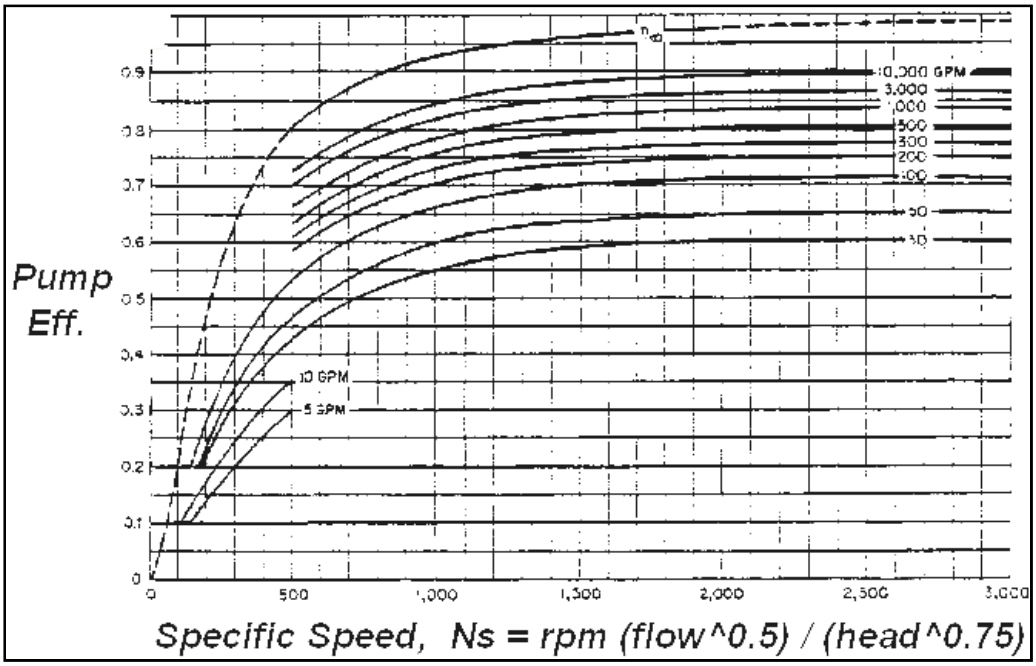


Figure 2: The graph of pump efficiency showing the pump specific speed
Source: Michael 1983

2.2.2 Fuel use Efficiency

The fuel consumption rate for the 10 pumps was measured at different pump operating speeds. Fuel consumption rate was measured concurrently with water discharge in order to evaluate the fuel used per volume of water pumped. The pumping time was measured using a stop watch.

The values for the fuel consumption rate of the different pumps were compared with the standards already set by manufacturers (Davis and shirtliff, 2001 and HondaAtlas Power Products Ltd,HAPPL),

2.2.3. Power Requirement Determination

Pump power requirements for the 10 irrigation setups was calculated from equation 2, which include power (KW) = Power requirements, Q = Discharge (m^3/hr), H = Head (m), Ep = Pump efficiency.

$$power(KW) = \frac{Q * H}{360 * Ep} * 1.2 \quad \text{.....(2)}$$

2.2.4 Economic Evaluation of Pumped Irrigation Systems

Pump fuel use during irrigation was evaluated for the 10 pumps used in different irrigation setups. This was further converted to the costs incurred during irrigation.

The overall seasonal energy cost was calculated from the seasonal energy demand, the fuel consumption of the pump, and the cost of fuel using equation 3. In this equation, OSEC – Overall seasonal cost, SED is Seasonal energy demand, F_UC is Fuel consumption, CF is Cost of fuel. The cost of fuel was determined from the local market rate at the time of project implementation.

$$OSEC(Ksh) = SED(Kwh) * F_UC(L/Kwh) * CF(Ksh) \quad \text{.....(3)}$$

where

SED was computed from equation 4, in which Q - volume of water (m^3), H - Head (m), Ep - pumping plant efficiency .

$$SED(Kwh) = \frac{Q * H}{367 * Ep} \quad \text{.....(4)}$$

EP is evaluated as shown in equation 5, where EP is pumping plant efficiency, PUE is Pumping plant efficiency, TE isTransmission efficiency, PE is Pump efficiency.

$$EP(\%) = PUE * TE * PE * 100 \quad \text{.....(5)}$$

The values for fuel efficiency varies from 90 -100% hence an average value of 95 % was used and the power unit efficiency for petrol pumps is 10% while for diesel engines it is 15-35 %, (FAO,1992). Therefore an average value of 25% was used for the diesel pumps.

Evaluation of fuel consumption was based on 0.09L = 1 Kwh for diesel and 0.11 L = 1 Kwh for petrol (FAO, 1992). Transmission efficiency for the pumps used is usually 100% due to direct coupling. The different crops grown were also put into consideration while comparing the total cost of production and the overall seasonal energy cost.

2.2.4 Gross Margin Analysis

The "gross margin" for an item is the sales revenue obtained from the item sold, minus the direct costs of producing (or in the case of a reseller, the cost of acquiring) and selling the item. The direct costs are the variable costs that go up or down based upon the number of units sold.

From the questionnaire, different parameters were obtained from the smallholder farmers. These included agricultural practices, crops grown, quantity and costs of various inputs used during farming and the output as well as sales of the farm produce. Other data regarding the farming enterprise were obtained from farmers records. From the data obtained, the gross margin analysis for the farming enterprise was computed. Crops considered were French beans, Tomatoes, Water melon and Baby corns.

3.0 Results and Discussion

3.1. Agricultural Activities in Yatta and Kakuzi Divisions

From the preliminary survey done in the two study areas, smallholder farming dominated the agricultural sector with majority of the farmers practicing irrigated horticultural farming. Most of the horticultural crops are grown for both local and export market. Table 2 summarizes the findings from the two study areas.

Table 2: Findings in the two study areas

	Mitubiri location of Thika District	*Kithimani Sub location of Yatta District*
Crops grown	Water melons, french beans, baby corns, vegetables, bananas, tomatoes, mangoes, and subsistence crops.	water melons, French beans, vegetables, baby corns, bananas, tomatoes, Baby corns, Vegetables, bananas, tomatoes, mangoes and subsistence crops
Pumping systems used	Small motorized pumps used to pump water.	Gravity fed systems common for most farmers while pumping was done in some farms.
Main water users	Small holder farmers, few large scale farmers, Few large scale farmers.	Small holder farmers, few large scale farmers
Natural vegetation	Indigenous trees	Shrub land dominates the area

3.2 Irrigation Practices in the Two Study Areas

The percentages of the farmers using different methods of irrigation in the study area are shown in figure 6. The study shows that very few farmers used modern irrigation technologies in the study area. This would be due to lack of advice on appropriate technologies available or financial limitations to obtain modern equipments for irrigation.

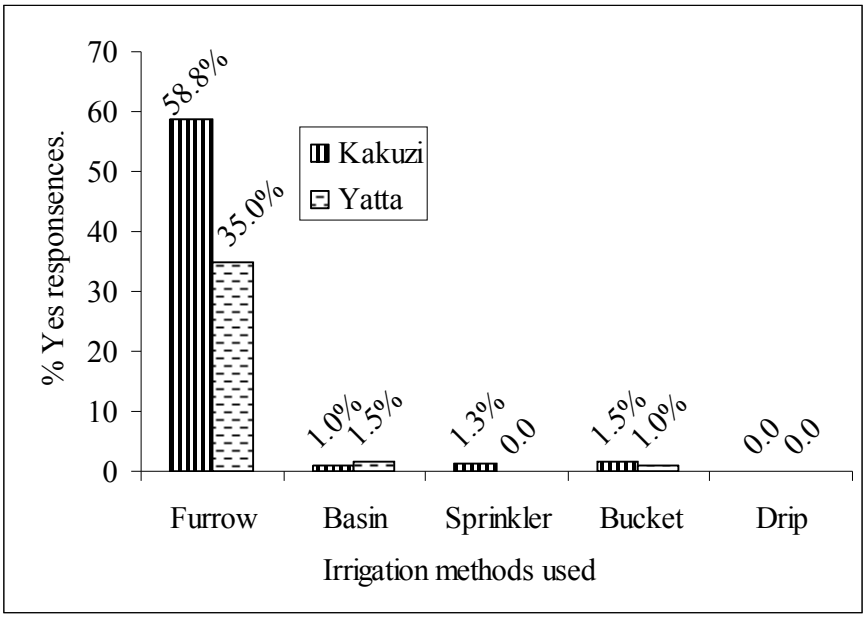


Figure 3: Smallholder irrigation methods used in the study sites

It was also found out that different on farm irrigation set ups were being used in the two areas. Majority of smallholder farmers 97.5% of respondents in the study areas use small motorized petrol pumps while 2.5% use diesel engine pumps. The farmers using petroll powered pumps gave the reason as the high cost of buying the diesel pumps as compared to petrol pumps. From the findings, it was concluded that there was low adoption of modern irrigation technologies by farmers. Few farmers used sprinkler irrigation in their farms while majority continued to rely on furrow irrigation method which apparently has very low water use efficiency (Hayrettin et al, 2008). The survey also found out that different on-farm irrigation set ups were being used in the two areas (Table 3). A large percentage of the farmers pumped water using small motorized pumps and conveyed it through pipes and then applied it directly in the furrows. The result shows that simple irrigation setups were being used by the farmers which they could probably understand and afford.

Table 3: On farm irrigation setups used by smallholder farmers

On farm irrigation set up	*No. of respondents*	*Percentage*
A) Pump-pipes-sprinklers	1	1.3
B) Pump-pipes – hosepipe – furrow	52	65
C) Pump – pipe –sub canal - furrow	8	10
D) Pipe- sub canal – furrow	15	18.8
E) Bucket	2	2.5
F) Pump – pipe – hosepipe – basin	2	2.5
	80	100%

3.3 Sources of Information in Purchasing Irrigation Equipments

Figure 4 shows different sources of information on where to purchase the irrigation equipments for the farmers in the study areas. 60% of the farmers get information on where to purchase the irrigation equipments from other farmers who have experience in using them.

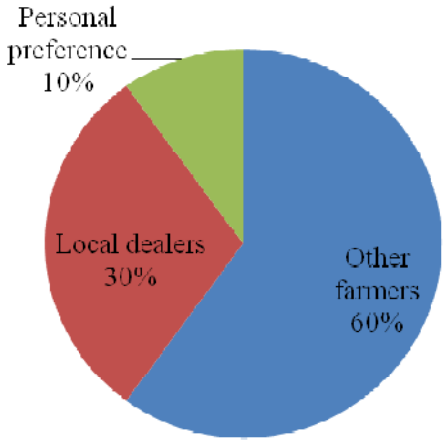


Figure 4: Source of information in purchasing irrigation equipment

Further information revealed that the farmers depended on past experiences in dealing with irrigation equipments and that no information was provided by irrigation personnel's or engineers in the two areas. This therefore indicates that there was no engineering approach that was adopted in selection, design and operation of the irrigation equipments. It was also found that the local dealers who sell the irrigation equipments provided information on the best equipments to use. The problem of lack of proper selection of irrigation equipments hence poor design were further cited by Kay et al., (1992) and FAO (1992).

3.4 Limitations of Pumped Irrigated Smallholder Agriculture

Several factors were found to have a negative influence in smallholder irrigated agriculture. Figure 5 shows in percentage the factors that limit pumped irrigated agriculture as cited by respondents in Mitubiri location and Kithimani sublocation.

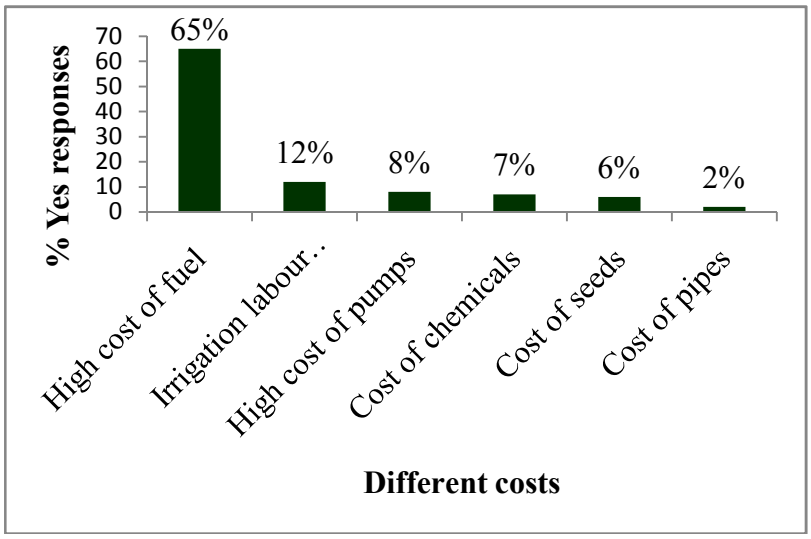


Figure 5: Limitations of smallholder pumped irrigation systems

High cost of fuel as cited by 65 % of the respondents was found to be the most limiting factor in pumped irrigated agriculture. Past studies done showed that there are several ways of reducing the high cost of irrigation such as embracing the agronomic, engineering and management techniques (Seckler, 1996).

3.5 Challenges Facing Smallholder Pump Fed Agriculture

Problems experienced by smallholder irrigated agriculture were given as poor markets for their produce, water shortages, lack of irrigation infrastructures, and high cost of inputs among others. Some of the challenges cited are shown in figure 6.

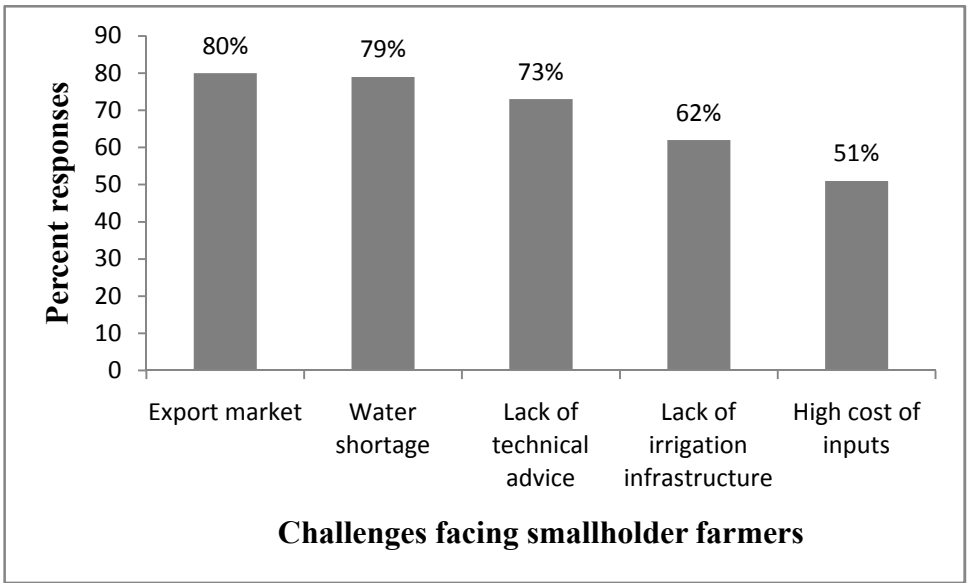


Figure 6: Challenges facing smallholder farmers

The challenges shown in figure 6 coincide with those shown by Mati et al., (2005) and Kulecho et al., (2006). Technical advice regarding irrigation equipment selection, design and operation was generally lacking in the two study areas. Inadequate technical capacity affecting farmers' organization and participation was also common which is further indicated by past studies done by Mati (2008). Export market for horticultural crops posed a major problem for most smallholder farmers which was indicated by 80% of the respondents. This was further aggravated by unreliable market prices and middlemen who swindle them of the profits they make. Water shortage during times of high demand of the horticultural crops was prominent in the study areas. It was further found that traditional methods of irrigation such as furrow irrigation was most common and could be the major contributor of water shortage due to its high water use inefficiency.

3.6 Technical and Economic Evaluation of Smallholder Pumped Irrigation Systems

3.6.1 The Pumps Used In the 10 Farms

Different types, makes and models of pumps were found in the two study areas. All the pumps used in the 10 farms were small motorized centrifugal pumps run by petrol and ranging from 4.0 to 6.6 horsepower. The total head for the different pumps ranged from 28 to 32m while the discharge rate varied from 520 L/min to 1100L/min. The pumps had varied inlet and outlet diameters ranging from 1.5 inches to 3 inches respectively. All the pumps had varied fuel consumption rate.

3.6.2 Pumps Working Efficiencies

The results showed that most pumps operated below the manufacturers recommended optimal design efficiency of 60% or higher (FAO, 1992). A pump operating at 60% efficiency is considered to be operating within its recommended range. Of the 10 pumps assessed, 6 of them operated below the recommended efficiency. Figure 7 shows the graph of pump efficiency for the 10 pumps assessed.

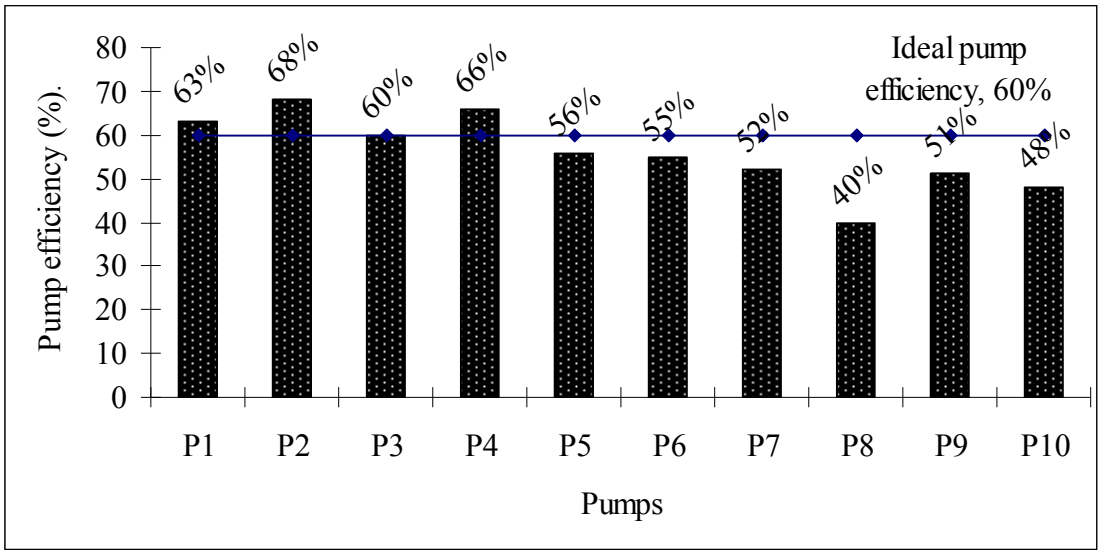


Figure 7: Efficiencies of different pumps used by smallholder farmers

Pump efficiency is a factor of many components such as pump specific speed, water discharge rate, rotating speed of the pump impeller and total dynamic head. An increase in the pump rotating speed and discharge rate of the pump results to an increase in pump specific speed which in effect results to increased pump operating efficiency. On the other hand, an increase in the total dynamic head results to reduced pump specific speed which then lowers the pump operating speed. It is therefore important to match all the pump parameters in order to ensure that the pump operates at the highest level of efficiency as possible. Despite the fact that the pumps were of different makes and model, the operational factors should be such that they ensure its operating efficiency remains as high as possible. Table 4 shows the operating conditions for the 10 pumps used in the study area.

Table 4: Operating conditions for the 10 pumps used in the study area

Pump	*Calculated specific speed, Ns*	*Operating pump speed N (RPM)*	*Average water discharge (L/s)*	*Total dynamic head (m)*
P1	1834	1800	3.0	6.3
P2	1730	2250	5.3	10.3
P3	1884	2200	2.2	6.4
P4	3115	2300	4.7	5.2
P5	1178	2400	2.4	11.0
P6	858	3200	2.8	24.3
P7	753	2550	2.9	21.9
P8	351	3000	0.2	13.8
P9	1172	2750	1.6	9.8
P10	1083	2600	1.5	9.4

From table 4, the total dynamic head for farm setups using pumps 6, 7 and 8 were higher compared to the other pumps used in other farm setups. This could have possibly lowered the pumps operating efficiency. The discharge rate for the farm setups using pumps 3 and 6 exceeded the design limit hence

could have resulted to poor pumps operating efficiency. Further investigation on relationship between pumps age versus efficiency showed that pumps age did not affect its efficiency. Some old pumps had a higher efficiency than the new pumps. Several factors that could have contributed to this anomaly were either repair or maintenance, pumps make and model as well as proper operation of the pumps.

3.6.3 Fuel use Efficiency

The running speed of the pump was found to have a big influence on fuel use. Figures 8 and 9 shows the fuel use versus running speed of 10 pumps.

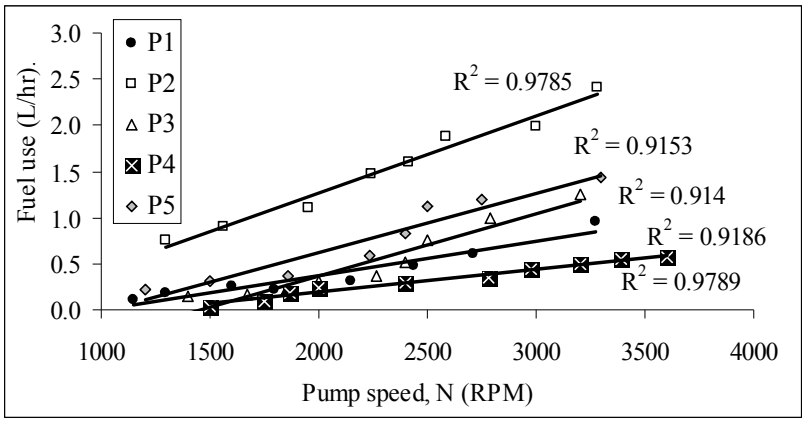


Figure 8: Fuel use versus pump speed for different pumps in Kithimani Sub location

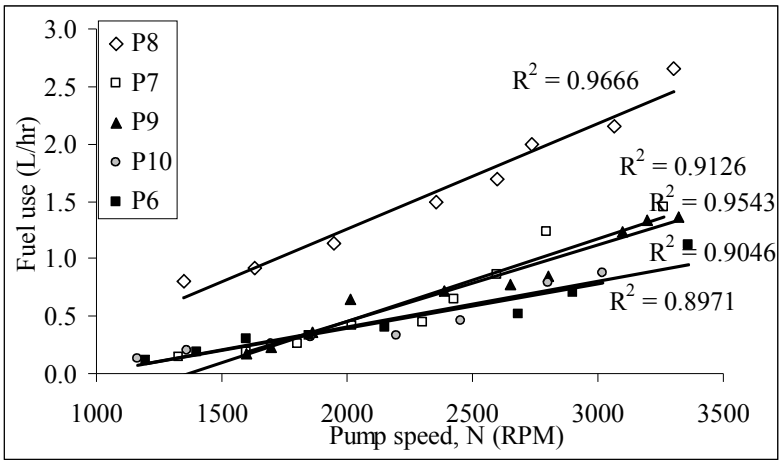


Figure 9: Fuel use versus pump speed for different pumps in Mitubiri Location

A regression analysis indicated that the fuel consumption rate of the pump depended on the pump running speed. The relation is actually linear with R^2 for the pumps lying between 0.89 to 0.98. A slight change in pump running speed greatly results to increased fuel consumption rates of the pumps. Increase in pump speed results to increase in fuel use while water discharge rate is increased. As a

result, by increasing the discharge rate, irrigation time is shortened. Farmers should operate their pumps at a speed that results to considerable fuel use while discharging manageable water.

Comparison of manufacturer's pumps fuel consumption rate versus the measured fuel consumption rate is shown in Table 5.

Table 5: Comparison of fuel consumption rate

Pump	*Manufacturers fuel consumption rate (L/hr)*	*Measured fuel consumption rate at optimum pump speed (L/hr)*
P1	1.25	0.96±0.14
P2	1.25	2.41±0.09
P3	1.50	1.26±0.10
P4	1.25	0.60±0.11
P5	1.25	1.44±0.13
P6	0.90	1.12±0.11
P7	0.90	1.45±0.12
P8	1.25	2.65±0.08
P9	0.90	1.36±0.15
P10	1.25	0.87±0.14

Mean ± STDEV

The manufacturers fuel consumption rates are the values when the pump operates at full throttle (maximum speed). Fuel consumption rate of the different pumps was measured at the pump operating speed. The farmers could not operate their pumps at full throttle considering the maximum allowable pipe discharge rates. Pumps 1, 4 and 10 representing 30% of the studied pumps consumed fuel at a rate slightly closer to the manufacturer's rated fuel consumption rate at full throttle. This indicates that the pumps were functioning normally during the time of assessment. The remaining pumps consumed slightly more fuel than the manufacturers prescribed rate. The reason for higher fuel consumption rate could be due to poor system maintenance or some broken down parts. It is therefore necessary to monitor the fuel consumption rate of the pumps more frequently in order to correct any arising anomaly. This could be as a result lead to lowered energy uses during pumping.

3.6.4. Fuel use and Cost

Figure 10 shows the fuel used in litres per hectare for the 10 farms assessed using different pumps with different fuel consumption rates while Table 6 classifies the fuel use range for the different farm setups.

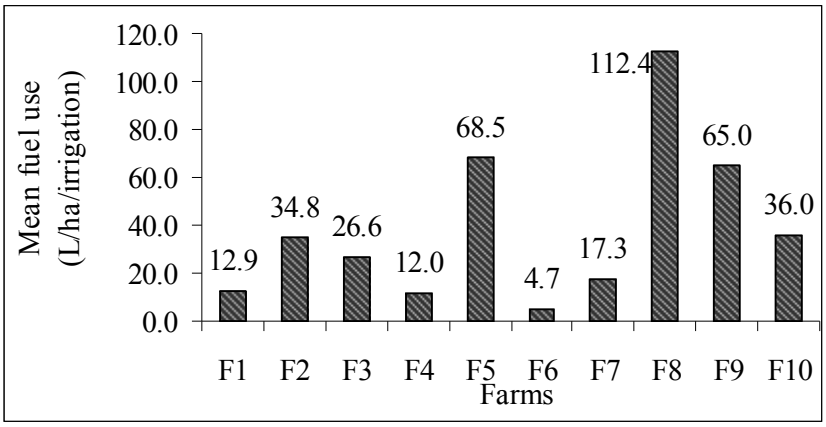
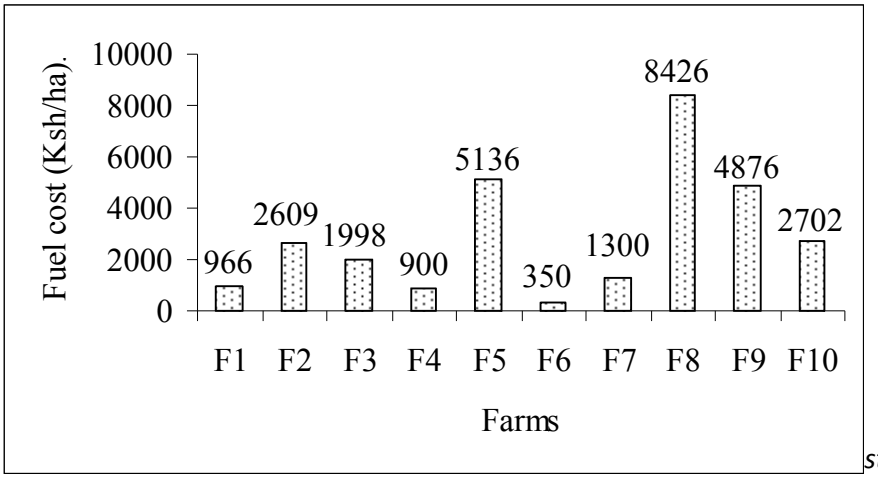


Figure 10: Mean fuel used per irrigation (L/ha) in the 10 farms

Table 6: Quantity of fuel used during irrigation

Fuel use range (L/ha/irrigation)	Farm irrigation setup
<5	F6
10-20	F1,F4,F7
20-40	F2,F3,F10
>60	F5,F8,F9

The 10 farm set ups showed wide variation in the amount of fuel used per irrigation for 1 hectare of land. Only one farm irrigation setup used less than 5 litres per hectare during irrigation while 3 setups used between 10 to 20 litres and a further 3 setups used greater than 60 litres per hectare during irrigation. This shows a wide variation in fuel use in irrigating the 10 different farms and the possible causes of this variation could be due to use of different makes and models of the pumps with differences in fuel consumption rates, different sizes of pipes and fittings used, farm orientation (elevation, length) and irrigators perception on the amount of water to apply and irrigation time. Different crops at different growth stages have different water requirements and this could have led to variation in irrigation time for the 10 farm setups, and the wide variation in fuel cost used (Figure 11). The differences could result to some farms operating at a loss or on marginal profit with others having more returns on investment. Matching the pump to the farm conditions is another factor in consideration. Frequent repair and maintenance as well as routine checkups of the pumps devices and irrigation equipments used would ensure reduced operating costs as well as higher returns on investments.



stimates)

Figure 11: Fuel cost per irrigation (Ksh/ha)

3.6.5 Evaluation of Overall Seasonal Energy Cost

The overall seasonal energy cost (OSEC) for the crops whose gross margin analysis was done was evaluated. Figure 12 compares the values for OSEC/ha for the three crops considered.

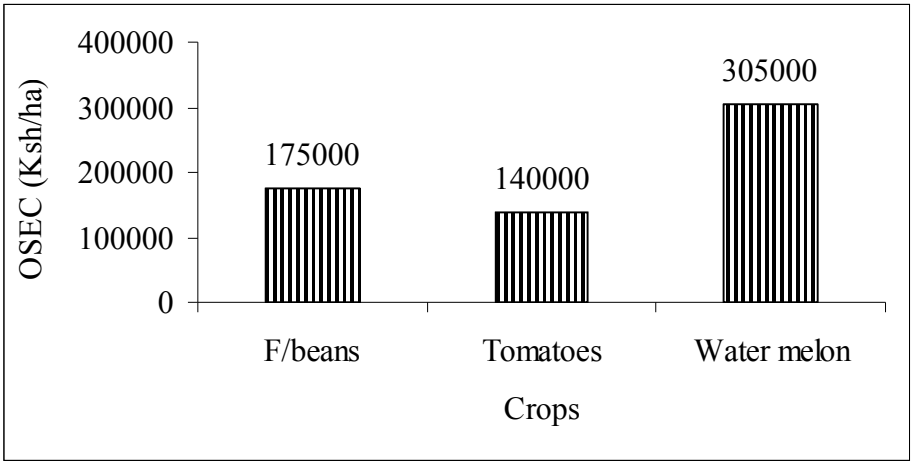


Figure 12: Average values for OSEC/ha for different crops grown by different smallholder farmer

The OSEC for water melon was almost double that of French beans. Tomatoes yielded the least OSEC/ha for the period considered in crop production. OSEC is a function of different factors such as pump operating efficiency, fuel consumption rate of the pump, cost of fuel, volume of water used during irrigation, total dynamic head, transmission efficiency and power unit efficiency. Among these factors, only the cost of fuel, transmission efficiency and power unit efficiency were constant while the rest varied from one farm setup to the other. Farmers should therefore aim at ensuring the varying constants operate as close to an ideal case.

3.6.6 Gross Margin Analysis of Smallholder Pumped Irrigation Systems

Gross margin analysis for smallholder pumped irrigation systems was carried out to assess the profitability of this type of farming with a view of identifying the most limiting factors.

Gross margin analysis of three different crops i.e. tomatoes, French beans and water melons was done. Six farmers growing French beans and had adopted the same crop spacing of 5cm by 30cm were

selected randomly from Mitubiri location. Similar crop spacing was to minimize variation in total production from the different farms. Two farmers growing tomatoes and water melons were considered in computation of gross margin analysis. The spacing considered for tomatoes and water melons was 45 cm by 60 cm and 0.7 m by 1.6 m respectively for all the farmers. Table 7 shows the mean production per hectare versus net returns for each of the crops considered.

Table 7: Mean production per hectare versus net returns for different crops

Crop	*Production/ha*	*Units*	*Unitcost (Ksh/kg)*	*Totalcost (Ksh)*
French beans	11,800	Kilogrammes	40.00	214,840.00
Tomatoes	38,300	Kilogrammes	20.00	765,658.50
Water melons	16,900	Kilogrammes	15.00	253,690.00

Figure 13 shows the summary of gross margin costs for the different crops assessed in the field.

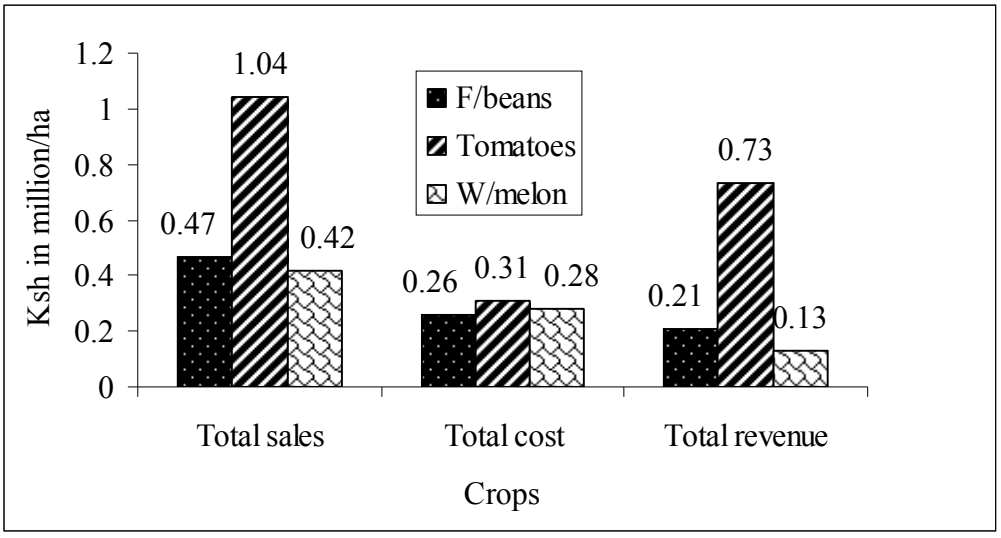


Figure 13: Gross margin analysis for different crops frown in the field

From the findings, tomatoes gave the highest returns per hectare of land while French beans and water melon were 2nd and 3rd respectively. Although the returns from Tomatoes were high as compared to the other crops considered, French beans were widely grown by the farmers in the study areas. This indicates that crop production for export market still plays a significant role in the agricultural sector and ought to be given the highest priority ever. Horticultural crops for the local markets generally fetched low prices with poor marketing structures hence resulting to farmers focusing on the export market despite its numerous challenges such as exploitation from the middlemen and at times lack of price awareness for their produce.

4.0 Conclusion and Recommendation

Despite the high uptake of smallholder pumped irrigation systems, it was found to have numerous challenges which ranged from engineering to management aspect. The numerous challenges that bedeviled the smallholder pumped irrigation systems were poor irrigation system component selection, design, inappropriate skills in running the systems as well as lack of technical support in selection and operation of these systems.

From the study, smallholder farmers were found to continually rely on traditional irrigation methods such as furrow system with few having modern irrigation systems. Lack of technical support in irrigation system selection, design and operation, further compounds the problems in smallholder irrigation systems. Some of the challenges affecting smallholder farmers operating pumped irrigation systems were poor market, high cost of fuel, water shortage, and lack of technical support as cited by 80%, 65%, 79% and 73% respectively as cited by the respondents.

6 of the 10 pumps assessed operated below the recommended design efficiency of 60% while fuel use for the 10 pumps varied from on pump to the other. The result of the variances in fuel consumption rates lend to some farming systems incurring more costs per unit of land irrigated.
The cost of fuel used per hectare varied from 350 Ksh/ha to 8426 Ksh/ha. The big discrepancy shows that it is possible to operate at a more hgher profit if all the factors leading poor performance are well thought of.

In general, smallholder pumped irrigation systems can be greatly improved by combining all the necessary factors ranging from engineering, agronomic and management.

ACKNOWLEDGEMENTS
The authors sincerely thank Jomo Kenyatta University of Agriculture and Technology for providing materials used in this study. The farmers who also participated in the study are also greatly acknowledged for their participation in making the study a success.

References

Abeer, M. H. (2007). Water Use Efficiency in Syrian Agriculture, NAPC, National Agricultural Policy Centre, Syria.

Allen R. G., Pereira L. S., Raes D. and Smith M. (1998). Crop evapotranspiration: guidelines for computing crop water requirements. Irrigation and drainage paper 56. FAO, Rome.

Bruinsma, J. (Ed.), (2003). World Agriculture: Towards 2015/2030, An FAO Perspective. Earthscan, London and Food and Agriculture Organization, Rome.

Charlotte D. F., David M. and Dennis W. (2009). Investing in water for food, ecosystems, and livelihoods: An overview of the comprehensive assessment of water management in agriculture. International Water Management Institute PMB, CT 112, Cantonments, Accra, Ghana. *Journal of Agricultural Water Management,* **97** (2010), pp 495–501.

Davis and Shirtliff., (2001). Product manual, Technical reference, Nairobi.

FAO.,(1992). Small-scale pumped irrigation: energy and cost. *FAO manual* prepared by Kay M and Hatcho N. Rome.

Food and Agriculture Organization (FAO), 2007. FAOSTAT database [http://faostat. fao.org/].

Food and Agricultural Organization of the United Nations, Rome.

Frederick, M. K., Lutta, M. and Samuel, M. W. (2000). Market survey report on market opportunities for fruits and vegetables processing in ukambani, Eastern Kenya.

Gathenya, J. M., (1999). ‘‘Einsatz von wasserhaushaltmodellen zur wasserbewirt-schaftung am Beispiel des Thika-Chania- Gebietes in Kenya’’, phD dissertation, institute for hydraulic engineering and water management, university of Kaiserslautern, Kaiserslautern.

Gay, B., (1994). *Irrigation Privée et Petites Motopompes au Burkina Faso et au Niger.* Paris: Groupe de Recherches et d'Echanges Techniques.

Honda Atlas Power Products (pvt) ltd (HAPPL)http://www.hondapower.net.pk/product_engines.htm (accessed on 5th November 2009).

Herdijk, A., Diemer, G., Kimani, J., Mukolwe, M. and Thairu, M, (eds)., (1990). Evaluation of Small-Scale Irrigation Development Projects: Smallholder Irrigation: A Large Challenge. Ministry of Agriculture, Irrigation and Drainage Branch: Nairobi, Kenya; Ministry of Development Cooperation: Netherlands.

Irrigation and Drainage Department (IDD), (2006). Irrigation sector in Kenya: status and challenges. Paper presented at Green Water Credits Workshop, 11-12 October 2006, KARI, Nairobi, Kenya.

Kibe, S. N., Kaluli, W., Home, P., Gathenya, M., (2007). Integrated water resources management for crop production and domestic water supply in Kaiti watershed, Eastern Kenya. MSc thesis. Biomechanical and Environmental Engineering Department, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya.

Kulecho, I. K., Weatherhead, K. (2006). Issues of irrigation of horticultural crops by smallholder farmers in Kenya. Springer Science Business Media B.V. 2006. Irrigation Drainage System.

Mati, B. M. (2002). Use of geographic information systems for planning and management of small-holder irrigation and drainage. In The Changing Face of Irrigation in Kenya: Opportunities for Anticipating Change in Eastern and Southern Africa, Blank HG, Mutero C M, Murray-Rust H (eds) International Water Management Institute (IWMI): Nairobi, pp 75–91.

Mati, B. M., 2008. Capacity development for smallholder irrigation in Kenya. International crops research institute for semi-arid tropics (icrisat), Nairobi, Kenya.

Mati, B. M., Penning D. V, F.W.T., (2005). Bright spots on technology-driven change in smallholder irrigation. Case studies from Kenya. In: Bright Spots Demonstrate Community Successes in African Agriculture. Working Paper 102: 27-47, International Water Management Institute.

Mbatia, E. D., (2006). Irrigation sector in Kenya- status and challenges, Nairobi, Kenya.

Michael, A. M., (1983). Irrigation theory and practice, vikas publishing house PVT ltd, Delhi, India.

Ministry of Agriculture and Livestock Development (MOALD), (1998). Annual Report for Agricultural activities, Thika and Machakos District, Kenya.

Molden, D. (Ed.), 2007. Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture. Earthscan, London and International Water Management Institute, Colombo.

Republic of Kenya, 2003. Summary of Strategic Plan (2003–2008). Irrigation and Drainage Department, Ministry of Water Resources Management and Development, Nairobi, Kenya.

Republic of Kenya, 2004. Strategy for revitalizing agriculture 2004–2014. Ministry of Agriculture and Ministry of Livestock and Fisheries Development, Nairobi, Kenya.

http://www.iwmi.cgiar.org/Publications/Working_Papers/working/WOR102.pdf [accessed in 2006].

Robinson, K., Thomas, M, and Catherine, N. (2005). District strategic plan 2005 – 2010, implementation of the national population policy for sustainable development, published by National Coordination Agency for Population and Development.

Seckler, D. (1996). The new era of water resources management from “dry” to “wet” water savings. IIMI Res. Rep. 5. Int. Irrig. Mange. Inst., Columbo, Sri Lanka.

Terry A. Howell, 2001.Enhancing Water Use Efficiency in Irrigated Agriculture.

Published in Agron. J. 93:281–289 (2001). USDA-ARS, Conserv. and Production Res. Bushland, TX 79012. Contrib. from the USDA-ARS, Southern Plains Area, Conserv. and Production Res. Lab., Bushland, TX 79012.

USDA. 1970. Irrigation water requirements. Technical Release no. 21. USDA Soil Conservation Service, Washington, DC.

A SURVEY OF PESTICIDE USE AND APPLICATION PATTERNS AMONG FARMERS: A CASE STUDY FROM SELECTED HORTICULTURAL FARMS IN RIFT VALLEY AND CENTRAL PROVINCES, KENYA

W. O. Nyakundi, G. Magoma, J. Ochora and A. B. Nyende
Institute of Biotechnology Research, Jomo Kenyatta university of Agriculture and Technology, Nairobi, Kenya
E-mail: nyakundi.william@yahoo.com

ABSTRACT
About 25-35% loss in agricultural produce is caused by pests and diseases which can be controlled by use of pesticides. These pesticides kill or deter the destructive activity of the target organism and they posses' inherent toxicities that endanger the health of the farmers, consumers and the environment. This leads to a need to study or assess pesticide usage patterns and applications on horticultural farms. To this effect a survey was carried out in Rift Valley and Central provinces of Kenya between October 2009 and January 2010 on horticultural farms producing either kales, french beans, cabbage, eryngium, morbydick and arabicum. Results indicated that pesticides are readily available and widely used in farms and the main herbicides in use were identified as linurex 50 wp and diurex 80wp while insecticides included diazol 60EC and methomex 90S, fungicides included folicur EW and dithane M45. Sixty (60%); of the respondents were Male and 40% female between the age of 20-60 years with an average age of 45 and a standard deviation of 13.3 years. Eighty (80%) of the respondents agreed to use hats, gloves for protection but they were not in good condition thus exposing them to pesticides. The pesticides affected the environment by citing death of fish in nearby rivers. The most frequently mentioned source of information on clinical usage was from commercial media (37.6%), government agricultural extension officers (26.4%), village leaders (25%) and finally the opinions of other community leaders. Educational interventions are essential for promoting safety during all phases of pesticide handling. Public policies should be developed to encourage farmers to change their pest management methods from chemical based to methods that are healthier and more environmentally friendly.

Key words: Pesticides, horticultural farms and pesticide application

1.0 Introduction

Agriculture accounts for about 24% of Kenya's GDP with an estimated 75% of the population depending on the sector either directly or indirectly. Much of the intermittent strength and overall weakness in GDP and income growth in Kenya can be attributed to changes in agricultural performance. The horticulture sub-sector of agriculture has grown in the last decade to become a major foreign exchange earner, employer and contributor to food needs in the country. Currently the horticulture industry is the fastest growing agricultural subsector in the country and is ranked third in terms of foreign exchange earnings from exports after tourism and tea. Fruits, vegetable and cut flower production are the main aspects of horticultural production in Kenya (Export processing zones authority, 2005).

As an agricultural economy, Kenya's demand for pesticides is relatively high. The import demand is further fuelled by regional consumption in land locked countries like Uganda, Rwanda and Burundi. Indeed the development of horticultural farming in Kenya equally increased the demand in the late 1990's (Paul, 2005). Kenya imports approximately 7,000 metric tones of pesticides worth billions of Kenya shillings (US$ 50 million). These pesticides are an assortment of insecticides, fungicides, herbicides fumigants, rodenticides, growth regulators, defoliators, proteins, surfactants and wetting agents. Of the total pesticide imports, insecticides account for about 40% in terms of volume (2,900 metric tones) and 50% of the total cost of pesticide imports (Ngaruiya, 2004).

Pesticides were brought into Kenya by the colonial government early in the 1920's. The earliest British government legislation, the Public Health Act, to protect human beings and regulate the use of pesticides by farmers in Kenya was enacted in 1921. Therefore, the toxic effects of pesticides were observed very early, soon after their application in the environment. It must be concluded that the early observed adverse effects of pesticides on humans necessitated the regulation of their use and handling (Shem, 2001). In recent years, concern has been growing that improper agrochemical use can create hazards for humans and the environment. Along with the green revolution policy around the world, the use of pesticides has skyrocketed over the past 40 years (Harris, 2000).

Challenges facing the horticultural industry in Kenya are to produce pest/damage free products, which are also pesticide residue free. The only way to come out of the puzzle is to adopt natural pest control methods. The Kenya horticultural industry is the second largest foreign exchange earner after tea. It earns US$300,000,000 annually. It creates employment to both the rural and the urban populations estimated at 500,000 and over 2 million people respectively (Mehrdad, 2004). Kenya is the largest flower exporter to the EU, with 25% of the market share, where 50,000 tonnes of flowers are exported annually. The horticulture industry is the major consumer of pesticides and the export market customers now demand a reduction in pesticide use (Mehrad, 2004).

1.1 Statement of the Problem

The heavy use of pesticides has resulted in various negative health, environmental and economic consequences (Ashburner and Friedrich, 2001). The Food and Agricultural Organization (FAO) FAO (2008), has been concerned about various reports of ill health associated with those applying pesticides. The World Health Organization had estimated that a million people were being poisoned annually with 20,000 cases resulting in death (WHO, 2006). Much of this problem was due to the toxicity of the pesticides that are used by many farmers but without adequate knowledge and failure to wear appropriate protective clothing. Health problems associated with pesticide application are usually blamed on the pesticides without considering how they are applied (PCPB, 2005).

1.2 Justification

Pesticides abuse and misuse is common in Kenya and in Africa, although the use of pesticides in Africa represents a small fraction of the global total, misuse is disproportionately high Factors that lead to these high misuse rates include the high illiteracy levels and inaccessibility to reliable protective clothing. Smuggled products, unregistered products, open air sales, sale of banned product, cases of decanting and reweighing, faking of pest control products using counterfeit labels, sale of expired products with modified expiry dates are among the misuse cases that have been reported in Kenya. Spraying mistaken products has lead to the dead of hundreds of flock (PCPB, 2004). To promote appropriate use of pesticides and applications, it is critical to understand the current use of pesticides among farmers, who are the majority of the Kenyan agricultural labor force. Until now, there have been no published reports regarding the actual behavior of farmers pesticide use and applications patterns. For this reason, this study was conducted to determine pesticide use and application among farmers in Rift valley and Central provinces, Kenya.

1.3 Hypothesis

There is no misuse of pesticides and applications among farmers.

1.4 Objective

To determine the current pesticide use patterns and applications among farmers in Rift Valley and Central provinces of Kenya.

2.0 Materials and Methods

2.1 Description of Study Areas

The study was carried out in selected horticultural farms in Rift valley and Central Province, in Kenya. These are mainly agricultural provinces where the population producekales, cabbage, French beans and horticultural (flowers and vegetables) crop production. The majority of these produces are sold on the national market or exported. The survey sites selected were based on the proportion of full-time farm populations, cooperation from local leaders, and the willingness of farmers to participate. The farms selected were Wanduhi (1° 02’49.98”S 37 °05’43.66”E elevation 4869ft), Jkuat (1 ° 03’31.52”S 37 ° 00’46.98”E elevation 5014ft), Langalanga (0°18’27.87”S 36° 04’15.53”E elevation 6303), Kariandusi (0°26’58.39”S 36° 15’42.92”E elevation 6299ft), Longonot (0°50’27.08”S 36 ° 28’37.25”E elevation 7008ft) and Sher agency (0 ° 16’15.04S” 36 ° 22’34.33”E elevation 7783ft).

2.2 Data Collection

The data was collected by means of a structured questionnaire (Appendix 1) for information on farming systems, pesticide use and practices, applicator precautions/averting behavior and health/ environmental effects. The survey was divided into two major sections, one dealing with the socio-economics of pesticide use (for example production, pesticides used, protection, training, etc.) and another strictly dealing with the health of the farmer (for example questions on self-reported health ailments/ health-related habits, a general physical exam, and patch-skin and blood tests for pesticides). The survey was conducted during October 2009- January 2010. To minimize any possible reporting bias, the survey was conducted under agreement that the team would not reveal the identity of the farmers surveyed or the r

2.3 Data Analysis

Data was presented in tables, graphs, charts and analyzed using descriptive statistics, ANOVA, L.S.D, Chi-square tests; Extraction Method: Principal Component Analysis; Rotation Method: Varimax with Kaiser Normalization. a Rotation converged in 21 iterations.

3.0 Results

3.1 Population Dynamics

One hundred farmers voluntarily accepted to participate in this study. The majority were males (60%) and females 40%. The respondents were 20-60 years of age with an average age of 45 and a standard deviation of 13.3 years. A considerable number either had finished primary school (24%), Secondary school (50%), College (15%) and no schooling (8%) (Figure 1). Some farmers reported growing more than one kind of crop on their lands. Variety of flowers (50%) were found to be the major produce, followed by kales (40%), French beans (20%) and bananas (15%) Most farmers had worked on these farms for more than 5 years.

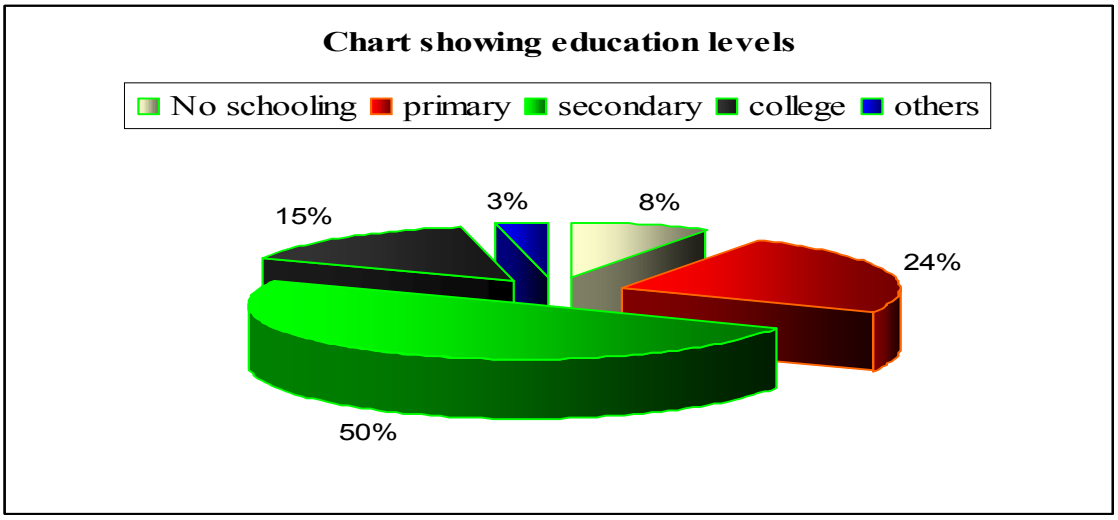


Figure 1: Showing education levels and % of response in each category

3.2 Pesticide Utilization

The vast majority (63%) of respondents reported using same dosage of pesticides in crop production, while (25%) decreased and (12 %) increased the dosage. All pesticides were stated by their trade names without any awareness of the common names. Among them, the most frequently mentioned were insecticides, followed by herbicides, fungicides, bactericides and nematicides as shown in Figure 2 below. Some of the pesticides were extremely hazardous or highly hazardous (World Health Organization, 2005). Diazol 60EC, a pesticide in the organophosphate family, was the most frequently used by farmers, followed by methomex 90sp, which is in the carbamate family. Glyphogan 48 SL was the most popular herbicide, whereas the combination of linurex and touchdown was the most frequently mentioned fungicidal agent.

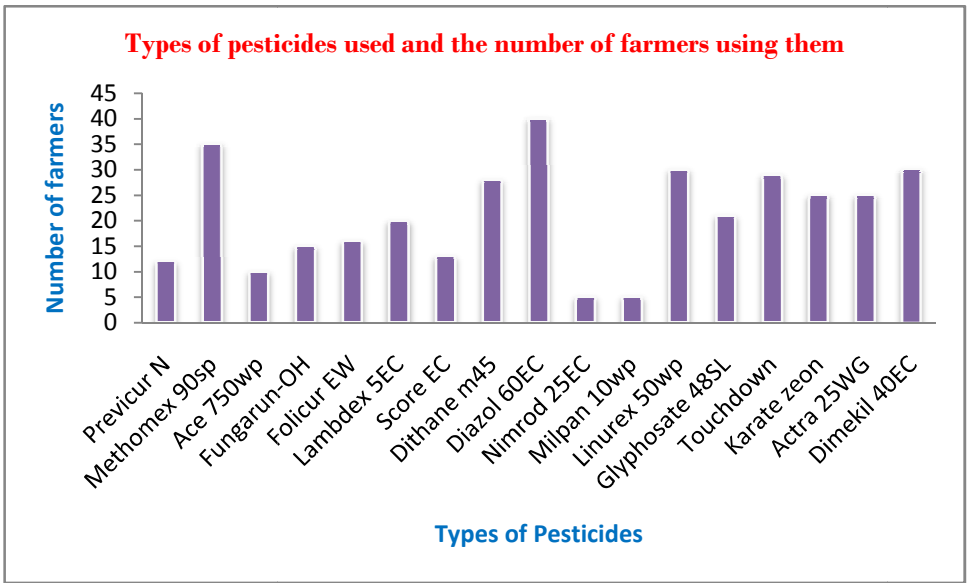


Figure 2: Showing the types of pesticides used and the number of farmers using them

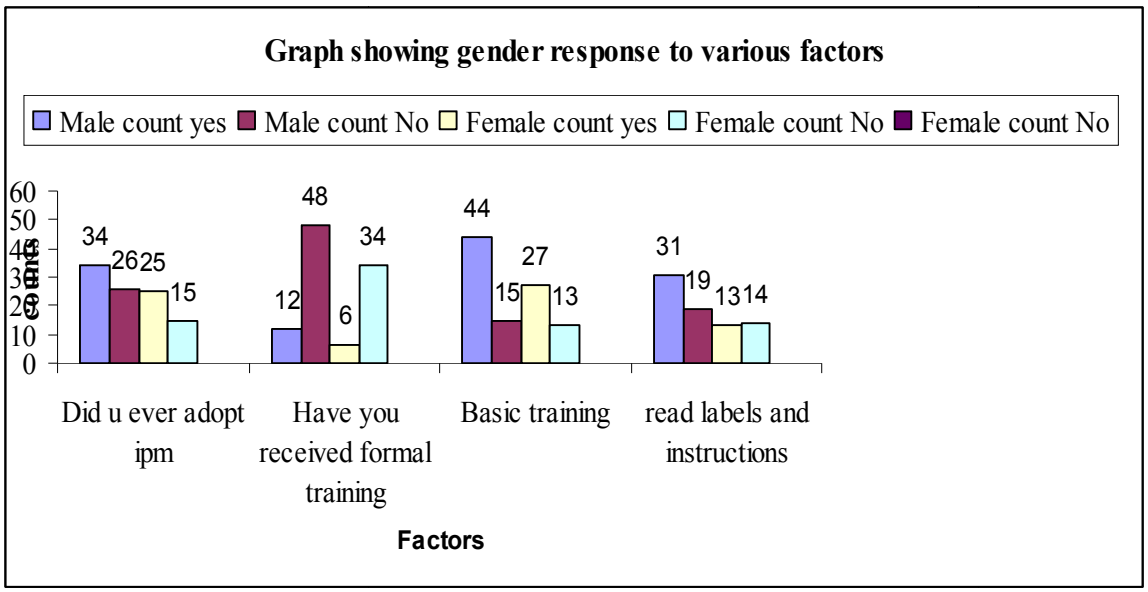


Figure 3a: A cross tabulation count of gender (Male and Female) response to various dependable variables

Cross Tabulation of Sex % Response within Sex and Within the Dependable Variables

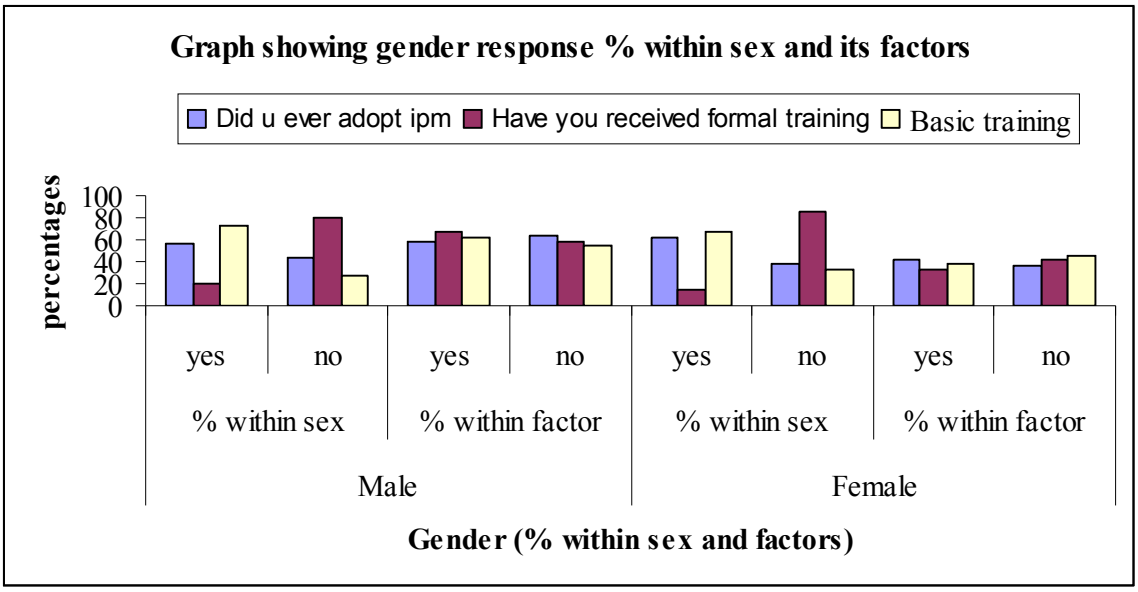


Figure 3b: Gender % response within sex and within the factors

The Table 1 below shows Pearson chi-square test for gender with different dependable variables

Table 1: Pearson chi-square test for sex (Gender)

Dependable variables	Value	Asymp. Sig(2-sided)
Did u ever adopt IPM technique	0.338	0.561
Have you received formal training	0.407	0.524
Basic training	0.397(b)	0.529

Cross Tabulation of Education Counts with other Dependable Variables

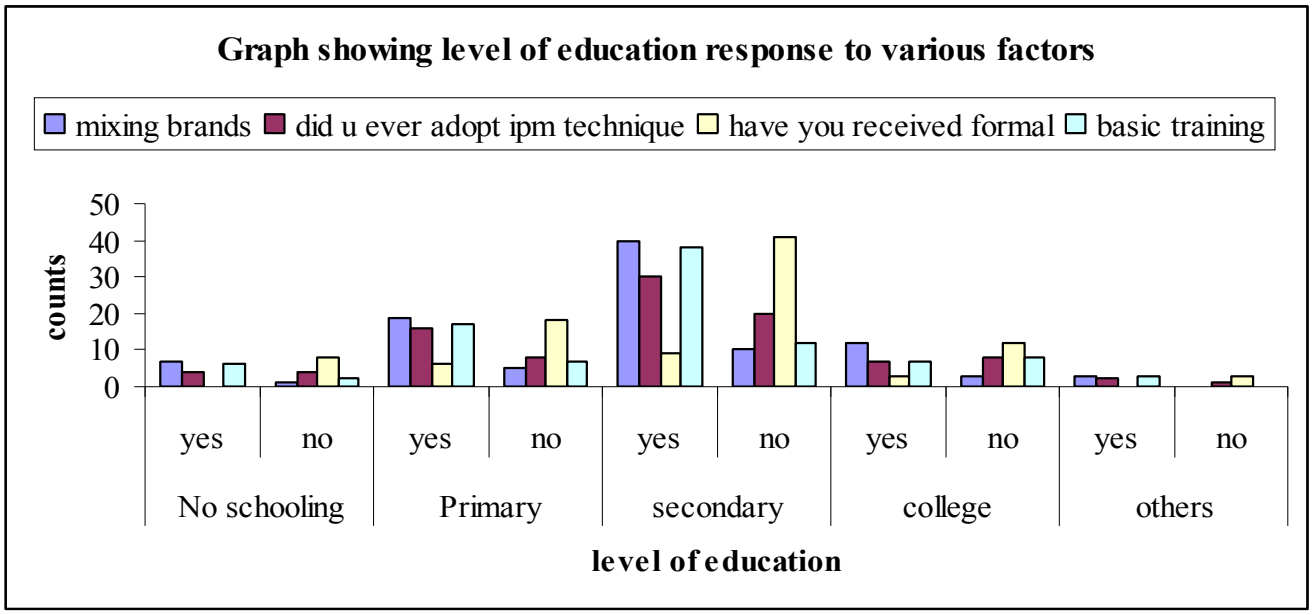


Figure 4a: Education level and response to various factors

The table 2 shows Pearson chi square tests for education and various dependable variables

Table 2: Shows Pearson chi square test for education

Dependable variables	Value	Asymp.sig (2-sided)
Mixing brands	1.018(a)	0.907
Basic training	6.209	0.184
Have you received formal training	3.252(a)	0.517
Did you ever adopt IPM technique	1.888(a)	0.756

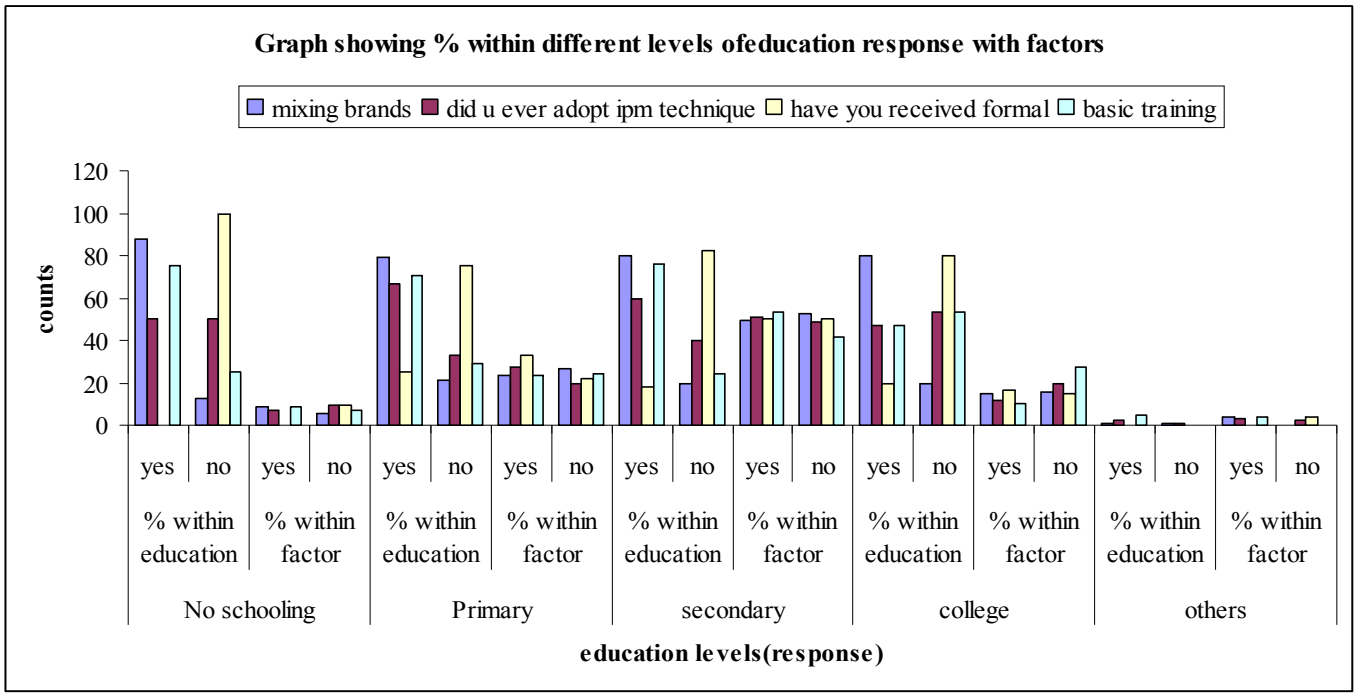


Figure 4b: Shows% within different levels of education and % within dependable variables

Cross Tabulation of Farm Counts to the Different Dependable Variables

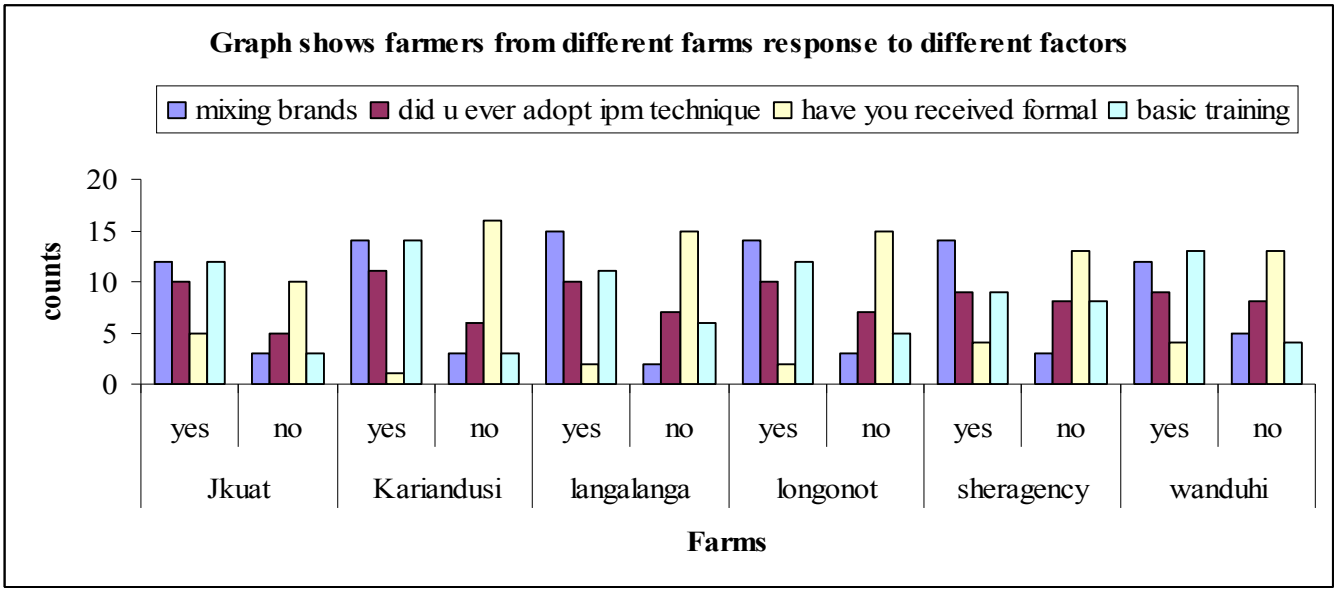


Figure 5a: Shows different farms and response to the various factors

The table 3 shows Pearson chi square tests for farms and various dependable variables.

Table 3: Shows Pearson chi square test for farms

Dependable variables	Value	Asymp.sig (2-sided)
Mixing brands	1.846(a)	0.870
Basic training	4.922(a)	0.425
Have you received formal training	5.680(a)	0.339
Did you ever adopt IPM technique	1.110(a)	0.953

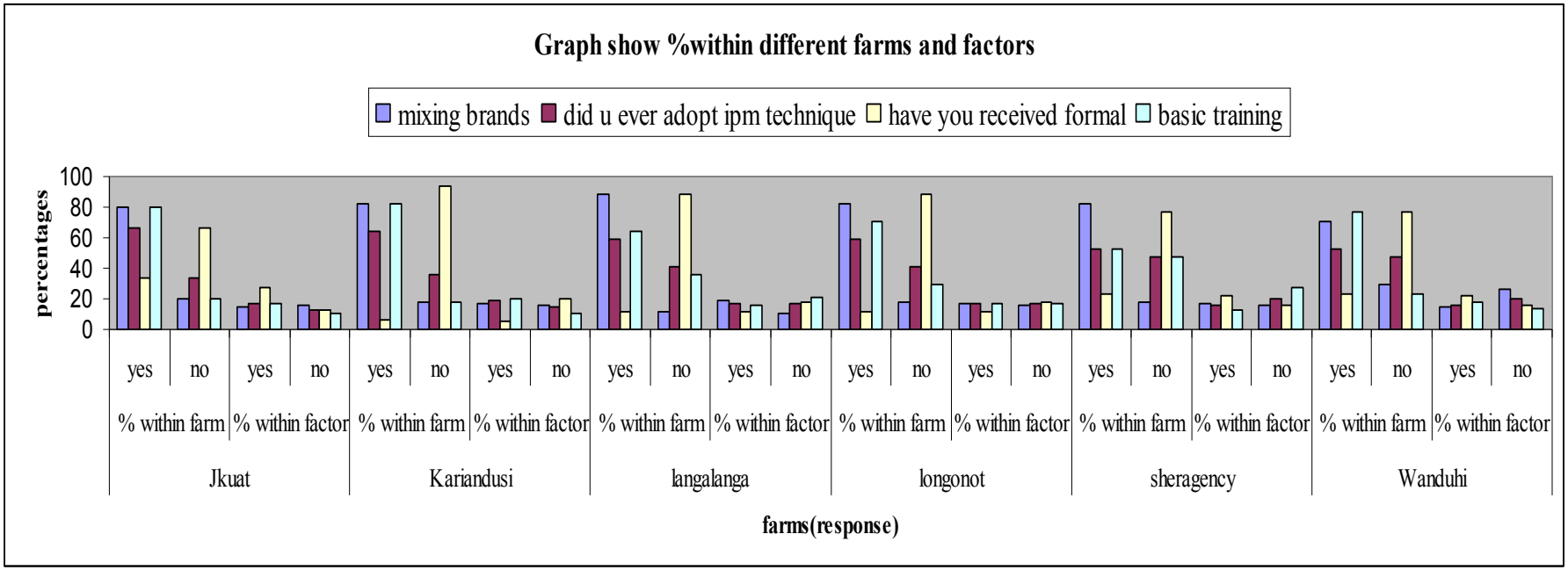


Figure 5b: % within different farms and % within dependable variables

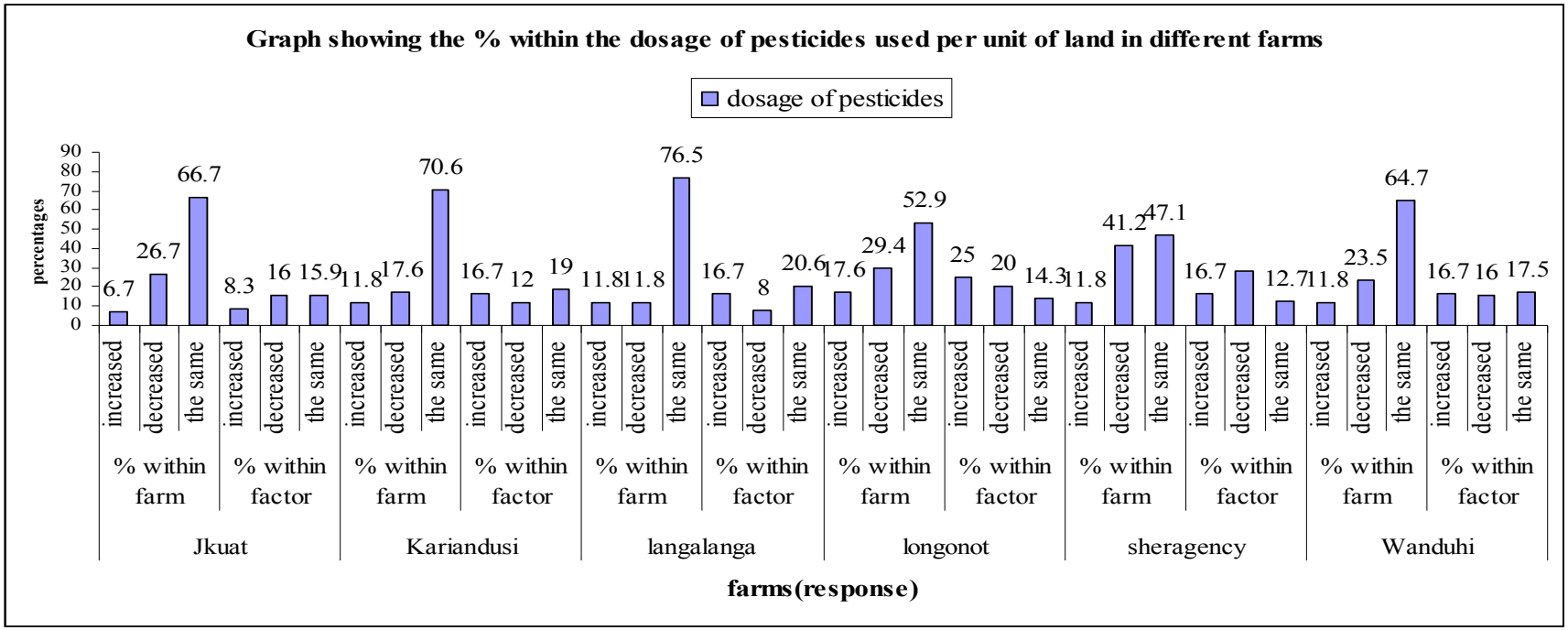


Figure 6: Shows the percentage within the dosage of pesticides applied/ used per unit of land in different farms

Table 4: Shows ANOVA table comparing Education with other dependable variables

dependable variables	*means*	*coefficient of variance*	*Significance (P)*	*F value*
Dosage of pesticides	83.6667	28.49201	0.9393	0.2
adoption of ipm technique	70.5	35.44855	0.7671	0.46
basic training	64.5	34.9509	0.188	1.57
mixing brands	59.5	33.65028	0.9125	0.24
do u practice reading labels and instr.	99	10.01201	0.2262	1.44

Table 5: ANOVA table comparing Farms with other dependable variables

dependable variables	*means*	*coefficient of variance*	*Significance (P)*	*F value*
Dosage of pesticides	83.6667	28.35083	0.7387	0.55
adoption of ipm technique	70.5	35.77765	0.9571	0.21
basic training	64.5	35.37639	0.4383	0.97
mixing brands	59.5	33.68699	0.8788	0.35
do u practice reading labels and instr.	99	10.10733	0.4371	0.98

Table 6: ANOVA table comparing Sex with other dependable variables

					T- tests			
Dependable variables	means	Coefficient of variance	Significance (P)	F value	Mean (M)	Critical value of t	Mean (F)	LSD
Dosage of pesticides	83.6667	27.93584	0.2033	1.64	86.111	1.98447	80	9.4679
adoption of ipm technique	70.5	35.1764	0.5658	0.33	71.667	1.98447	68.75	10.046
basic training	64.5	35.46194	0.5336	0.39	66.25	1.98447	63.333	9.2653
mixing brands	59.5	33.18555	0.4102	0.68	60.833	1.98447	57.5	7.9984
do u practice reading labels and instr.	99	10.11817	0.417	0.66	98	1.98447	100	4.0577

4.0 Discussion

This study was conducted on a small group of farmers in both rift valley and parts of central province, Kenya. Therefore, the results should be considered as a case study, generalizing these results to the national level should be done with extreme caution. The data relied mainly on the farmers' recollection. Discrepancies might have occurred due to recall bias and social factors.

Pesticides are used extensively on large farms and by parastatals organizations, largely concerned with export crops. The results of this survey indicate a wide variety of chemicals were utilized as pesticides in the area. The use of extremely and highly hazardous insecticides was observed. Other less hazardous agents create a health risk to the farmers as well (Epstein and Bassein, 2003).

A hundred respondents 60% being male and 40% being female agreed to participate in this survey. The age bracket of participants was between 20 -60 years with the average being 45 years. The level of education showed quite a number of respondents with no schooling (8%), primary (24%), secondary (50%), college (15%) and others (3%) as shown in figure 1. From this statistics it was evident that primary and secondary school students were the majority in these farms. Most of those with no or lesser education levels said it was due to lack of fees to further there education while for others it was due to lack of jobs and the need to earn money to sustain themselves.

Most of the farmers (85%) who were interviewed had stayed in the farms for more than 5 years, with others close to 15 years in the same farm and or lived in villages right next to the farms where they were working. The respondents (100%) agreed there was pesticide use on there farms and 75% were also responsible for what pesticide to buy. They also agreed that the pesticides were bought from more than one retailer (67%). The brands of pesticides used in the farms were regularly changed (60%) so as in order to combat resistant strains affecting farm produce.

Most of the respondents indicated that the pesticides Methomex 90sp and Diazol 60EC were the most frequently used as shown in figure 2. In cross tabulation of sex count with other dependable variables 34 Male accepted and 26 rejected having adopted the IPM technique while on the other hand 25 female accepted and 15 rejected having adopted the IPM technique. Most men (48) and women (34) denied having received formal training on the use of pesticides as shown in figure 3a. This so alarming because it leads to the misuse of pesticide applications and can lead to deaths. The percentage within sex in males (56.7%) who accepted adopting IPM was higher compared to the one's who denied (43.3%). While on the other hand (62.5%) of women % within sex accepted adopting IPM and (37.5%) denied as shown in figure 3b. This number is high compared with that of men who were the majority respondents with 60% at the beginning. We conclude that women are more willing compared to men. Asymp. Sig. is the estimated probability of obtaining a chi-square value greater than or equal to 0.338 if the experiment is repeated several times. For the variable did you ever adopt IPM technique the p = 0.561 meaning there will be no variations in the observed versus expected values in the experiment.

A huge percentage of men and women denied to having received formal education with the percentage within sex accounting for (80%) who denied in men and 85% in women as shown in figure 4a and b. It can be concluded that lack of formal education has contributed greatly to the misuse of pesticides and there applications.

As compared to education levels secondary (40) and primary (19) had the highest number of respondents who agreed to mixing of different brands of pesticides as shown in figure 4a and 4b. The main reason was to counter the different resistant strains affecting farm produce. In all the farms there was a majority (all farms) response compared to whether they changed the dosage of

pesticides applied per unit of land. Most farmers maintained the same dosage while others increased because the early dose did not work for them as shown in Figure 6.

In this survey, insecticides were the most frequently mentioned chemical utilized, followed by herbicides and fungicides. This may be due to differences in the types of crops cultivated in the area, for example, bananas in our survey, compared to kales. In general, weeds grow more rapidly where there is strong sunlight. The banana tree canopy is not suitable for the growth of weeds. For this reason, farmers in our survey reported the use of herbicides to the lesser extent than those at the national level.

Farmers relied mainly on commercial sources for information about pesticides, along with the influence of suppliers, whose goal was to maximize their sales volumes, resulting in down playing the negative impact of pesticides. Personal protection equipment and personal hygiene were inadequate. The main concern of farmers was to wear gloves and long sleeved shirts, and this was found to be practiced by more than half of the farmers. This finding indicates a correct knowledge of pesticide routes of absorption, where skin absorption, not inhalation, has been reported to be the most important. This finding is consistent with many other studies regarding handling of pesticide by rural farmers (Burleigh *et al.*, 1998; Berg, 2001; Matthews *et al.*, 2003; Isin and Yildirim, 2007).

In less developed countries, adequate protective clothing is often neglected for reasons of discomfort and/or high cost. No national regulations require farmers working with pesticides to observe specific precautions (Wilson and Tisdell, 2001). Proper pesticide waste disposal is also an important part of responsible pesticide use. Accidental release or uncontrolled discharge of pesticide waste into the environment can harm people and contaminate the environment (Damalasb *et al.*, 2008). In this study, the disposal of pesticide containers was found to be careless. Empty pesticide containers may often retain unacceptable quantities of pesticide residue if not rinsed properly (Miles *et al*, 1983). As in many other developing countries where empty pesticide containers are highly valued and sold or exchanged as storage containers for other materials, the majority of farmers in this survey sold empty containers to buyers who picked up the waste from the community. It is unclear what the buyers do with such containers.

Damalasb *et al.,* (2008), strongly against such practices, recommended puncturing empty containers to prevent re-use. In regards to pesticide acquisition, proximity to stores was the most important factor influencing farmers' practices. The most frequently mentioned source of pesticides was agro-chemical shops in their community. Contrary to concerns regarding the influence of commercial personnel on farmers' pesticide use patterns, sales persons from agro-chemical companies were rarely mentioned as a source of pesticide information. This may be because of the small size and isolation of the farm area surveryed, which made the survey areas unattractive for company sales persons. Promotional strategies often utilized for such areas are commercial media and public broadcasts, as was the case in this study. In any case, caution should be exercised regarding the misleading nature of the content of the advertisement. For example, advertisements on television regularly used movie stars and celebrities as role models to promote pesticides.

Evidence from this survey pointed toward the need for a comprehensive intervention to change farmers' pesticide use patterns. Short- and long-term measures, tackling determinants of inappropriate pesticide use in a holistic manner, should be implemented. This, of course, implies close collaboration between government at different levels and the private sector. The short-term remedy to the problem is to limit access to hazardous pesticides. All class I and II pesticides according to WHO classification should be banned from the market. Long-term measures should include an array of activities to empower farmers to healthier choices for pest management. This

must include knowledge of chemical hazards which should be disseminated to all farmers. Knowledge regarding personal protective equipment should be propagated.

Unfortunately, knowledge alone rarely translates into practice (Murray and Tayler, 2000). A broad variety of factors play a role in shaping farmers' actual pesticide practices since they act rationally within the context of their available resources and socioeconomic objectives (Rola and Pingali, 1993). Presently, chemical pesticides are currently the cheapest and most effective means to for pest control in the short run. The supply agents have been subsidized by the government to accelerate national crop production. Moreover, the popularity of chemical pesticides stems from their rapid action and prolonged duration (Food and Agriculture Organization of the United Nations, 2008).

5.0 Conclusion

The study indicates pesticide use in selected horticultural farms among farmers in rift valley and central provinces of Kenya. Findings of this study clearly suggest that it is necessary to reduce possible health and environmental risks associated with pesticide use by documenting risk perceptions and developing ways to address them. Further studies are warranted to generate appropriate data on which to base policies.

Acknowledgements

The authors are grateful to the Research production and extension department, Jomo Kenyatta University of agriculture and technology for the research grant. I also wish to sincerely thank Professor Gabriel Magoma, Prof. John Ochora, Dr. Aggrey Nyende, Mr. Rotich, Mr. Philip.

References

Ashburner, J. and Friedrich, T., (2001). Improving handling of pesticides application equipment for the safety of applicators. Pestic. Manage. West Africa, **2**, pp 9–11.

Berg H. (2001).Pesticide use in rice and rice-fish farms in the Mekong Delta. *Vietnam Crop Prot.,* **20**, pp 897-905.

Boonyatumanond R, Jaksakul A, Puncharoen P, *et al*. (2002). Monitoring of organochlorine pesticide residues in green mussels (*Perna viridis*) from the coastal area of Thailand. *Environ Pollut,* **119**, pp 245-52.

Burleigh J. R., Vingnanakulasingham V., Lalith W. R. B., *et al*. (1898). Pattern of pesticide use and pesticide efficacy among chili growers in the dry zone of NE Sri Lanka (System B): perception vs reality. *Agr Ecosyst Environ.*, **70,** pp 49-60.

Damalasb C. A., Telidis G. K., Thanos S. D. (2008). Assessing farmers' practices on disposal of pesticide waste after use. *Sci Total Enviro.n,* **390**, pp 341-5.

Epstein L, Bassein S. (2003). Patterns of pesticide use in California and the implications for strategies for reduction of pesticides.*Annu Rev Phytopathol,* **41**, pp 351-75.

Food and Agriculture Organization of the United Nations, Agriculture and Consumer Protection Department, 2008. Welcome to the page on Integrated Pest Management (IPM). [Cited 2008 Aug 15]. Available from: URL: http://www.fao.org/ag/AGP/AGPP/IPM/ Default.htm

Harris, J., (2000). Chemical Pesticide Markets, Health Risks and Residues. CABI, Wallingford.

Isin S, Yildirim I. (2007). Fruit-growers' perceptions on the harmful effects of pesticides and their reflection on practices: the case of Kemalpasa, Turkey. *Crop Prot*., **26**, pp 917-22.

Issaragrisil S, Chansung K, Kaufman DW, *et al*. (1997). Aplastic anemia in rural Thailand: its association with grain farming and agricultural pesticide exposure. *Am J Public Health*, **87**, pp 1551-4.

Mamat, M. J., Anas, A. N., Sarif Hashim, S. H., (1993). Safer pesticide application equipment for small-scale farmers in developing Asian countries. In: Forget, G., Goodman, T., de Villiers, A. (Eds.), Impact of Pesticide use on Health in Developing Countries. IDRC, Ottawa, pp. 178–185.

Matthews G., Wiles T., Baleguel P. (2003). A survey of pesticide application in Cameroon. *Crop Prot*,. **22**, pp 707-14.

Miles J. R., Harris C. R., Morrow, D. C. (1983). Assessment of hazard associated with pesticide container disposal and of rinsing procedures as a means of enabling disposal of pesticide containers in sanitary landfills. *J Environ Sci Heal B*, **18**, pp 305-15.

Murray D. L., Tayler, P. L. (2000). Claim no easy victory: evaluating the pesticide industry's global safe use campaign. *World Devel*, **28**, pp 1735-49.

Rola A. C., Pingali P. L. (19930. Pesticide, rice productivity, and farmers' health: an economic assessment. Laguna: International Rice Research Institute, Philippines.

Wilson C. Tisdell C. (2001). Why farmers continue to use pesticides despite environmental, health and sustainability costs. *Ecol Econ.*, **39**, pp 449-62.

World Health Organization. Sound management of hazardous wastes from health care and from agriculture. New Delhi; WHO South- East Asia Regional Office, 2006.

Zarcinas B. A., Pongsakul P., Mclaughlin M. J., *et al*, (2004). Heavy metals in soils and crops in southeast Asia. 2. Thailand. *Environm Geochem Health,* **26**, pp 359-71.

CHEMICAL CHARACTERISATION OF *HIBISCUS SABDARIFFA (*ROSELLE) CALYCES AND EVALUATION OF ITS FUNCTIONAL POTENTIAL IN THE FOOD INDUSTRY

Wahid A. Luvonga[1], M. S. Njoroge[2]., A. Makokha[3], P.W. Ngunjiri[4]
[1,2,3]Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[4]Kenya Industrial Research and Development Institute, Nairobi, Kenya
E-mail: abrahamwahid@gmail.com

Abstract
Antioxidant capacity, phytochemicals, phyto-nutrients and bioactive compounds, have all become buzzwords in the growing market for natural health food-products and speciality juice drinks. The main objective of this study was to determine the bioactive compounds in the calyces of *Hibiscus sabdariffa* L. and evaluate its functional potential hence provide an incentive to production, processing and consumption of roselle in Kenya where it is not widely cultivated and utilized. Proximate composition was determined using established AOAC methods. Antioxidant activity (AA) color degradation index (CDI) and were carried using 1-1 diphenyl picryl hydrazyl radical (DPPH) and hunters color meter respectively. HPLC, UV-visible spectrophotometer and atomic absorption spectrophotometer (AAS) were used to determine water soluble vitamins (WSV), total polyphenolic content (TPC) and mineral composition respectively. Product formulations were done and their consumer acceptability determined based on a 9-point hedonic. It was found that the properties of roselle extract before and after pasteurization included pH of 3.88 ± 0.00 and 3.42 ± 0.01, total acidity (as malic acid) of 2.24 ± 0.00 and 2.24 ± 0.03 %, total phenolic contents of 6.06 ± 0.18 and 5.82 ± 0.01 mg/g roselle extract, respectively. The antioxidant activities using DPPH assay with ascorbic acid standard, expressed as EC50 (Efficient Concentration) were 230.01 ± 2.40 and 235.34 ± 0.79 µg/ml, respectively. Iron and calcium were content was 8.59 ± 0.31 and 14.83 ± 0.60 mg/100g respectively. After sensory analysis, the pure roselle drink was generally more acceptable in taste, flavor, aroma, consistency and overall characteristics with an average overall score of 7.6 out of 9 in comparison with Rosela orange drink, rosella apple drink and rosella melon drink. These properties give roselle the potential as a functional ingredient in beverage manufacture and other applications such as utilization in polymeric natural color development. Roselle can also be applied in the food industry for manufacture of red wine and roselle fruit flavored preserves, thus exhibiting great potential in commercial application in the food and pharmaceutical industry. More studies for in-vivo properties of Roselle extracts are however needed, to further substantiate the health claims of roselle extract in human nutrition.

Key words: Roselle extract, bioactive properties, functional properties, antioxidant activity, food industry

1.0 Introduction

Recently there has been an increased interest in research on food components such as anthocyanins and other phenolic compounds because of their possible linkage to health benefits including reduction in heart disease and cancer, based on their antioxidant activity (Seeram *et al.,* 2002). With the global functional food and beverage market expected to reach $109 billion by 2010 (Watkins, 2008), diverse sources of phytochemicals are being explored. Kenya cultivates a wide range of fruits and flowers but some fruits/flowers with potential economic, nutritional and functional value remain underexploited.

Roselle is a tropical shrub with red or green inflated calyces. The calyces groups are red, dark red and green types. (Schippers, 2000).The different parts of roselle are seeds, leaves and calyces and this have been used as vegetables, source of oil, refreshing drinks and food preserves. The fleshy calyces roselle have been used in various countries in Africa and the Caribbean as food or a food ingredient such as jellies, syrups, beverages, puddings, cakes, wines and as a colorant. In addition to their use in food, various parts of the roselle plant have been used in traditional medicine for the prevention of disease such as cardiovascular disease and hypertension.

The rationale of studying roselle is to gather information that will provide an incentive for commercial utilisation in Kenya. In this study, the phytochemical composition of roselle was examined,and the functional potential and technological applications were also evaluated. The rate of anthocyanin destruction depends on many factors such as pH, temperature, intermolecular copigmentation, ascorbic acid, and oxygen concentration. The reactions are usually undesirable in juice processing and long-term product storage (Mazza and Miniati, 1993). Therefore, the present study also monitored quality changes and bioactive properties of roselle extract in plastic transparent containers as affected by pasteurization and storage conditions. Anthocyanins are labile compounds that will undergo a number of degradative reactions. Polyphenols in beverages are common because of their beneficial physiological effects on health (Bravo, 1998; Ina *et al.*, 2002).

Colour was objectively measured as well as pigment concentration based on Wrolstad (2005) approach. Colour is one of the first parameters that consumers base their judgment on whether to buy a food product or not. It was important to investigate the pigment degradation since it affects color stability.

The objective therefore of the study was to determine the quality changes and bioactive compounds in the calyces of *Hibiscus sabdariffa* and evaluate their functional potential in food product development.

2.0 Materials and Methods

The Roselle calyces were obtained from those cultivated at JKUAT farm .They were subjected to postharvest operations that included washing with tap water, sun-drying to 10% moisture content, then they were stored for subsequent extractions and analyses. Proximate composition of the extract calyces was determined using the AOAC methods (1995). Water Soluble Vitamins (WSV) were determined by a reversed-phase HPLC method by Ekinci and Kadakal (2005), modified from Cho *et al.,* (2000). The sample treatment consisted of solid phase extraction (SPE) with Sep-Pak C_{18} (500mg) cartridges that enabled separation of water-soluble vitamins and removed most of the interfering components. Total phenolics were extracted using a method developed by Kim and Lee (2002) with slight modifications. Prior to extraction, sundried roselle were ground and homogenized. A 1g sample was extracted in 40ml of 80% methanol (V/V) in the dark for 1 hour at room temperature. The extract was centrifuged at 10,000rpm, filtered with whatman filter paper, re-extracted with 80% methanol and concentrated with a rotary evaporator. The phenolic extract was used for all the phytochemical analyses. The radical-scavenging capacity (RSC) was determined using 1-1 diphenyl picryl hydrazyl radical (DPPH) according to Ayoola *et al.,* (2006). All tests were run in triplicate, and analyses of all samples run in duplicate and averaged. Wrolstad (2005) approach was used to monitor color changes as affected by processing temperature and storage conditions for 60 days. The pasteurization temperatures were 60^0 , 80^0 and 100^0C. The products were stored at ambient and cold storage conditions for a period of 60 days.

Three beverage product categories of rosella orange drink (ROD), rosella apple drink (RAD) and rosella melon drink (RMD) were formulated in the rations of (roselle extract: fruit juice pulp) 1:1, 3:1 and 3:2 for each category respectively. The developed products were then randomly subjected to sensory evaluation to determine the most preferred. This was done by a team of 15 trained panelists who represent the common consumers most likely to use the product. Each panelist recorded their degrees of likes and dislikes using a nine point hedonic scale (Ihekoronye and Ngoddy, 1985). Before each sample testing the panelists rinsed their mouth with water to avoid cross interaction of product sensorial properties. The assessment was carried out under natural light at a temperature of 25ºC.

3.0 Results and Discussions

3.1 Proximate Composition

The proximate analysis of roselle calyces is presented in Table 1. The roselle calyces were relatively high in carbohydrates, crude fibre and ash. The carbohydrate content of the calyces is high. The high carbohydrate content obtained lends further support to the assertion of Babalola (2000) and Ojokoh (2003) that the Roselle calyces contain high carbohydrate contents.

Table 1: Proximate analysis of Roselle calyces (g/100g) dry mater

Parameter	Value
Ash Content	12.2
Fat Content	2.0
Crude Fibre	14.6
Protein Content	4.7
Moisture Content	7.6
Carbohydrate Content	68.7

3.2 Mineral Determination

Roselle calyces were found to be relatively high in K, Na. Mg, Ca and Fe as presented in Table 2. These values are relatively high implying that roselle can be a useful source in enriching other food products that are not rich in essential minerals. Potassium was found to be the most abundant mineral. Potassium is not only for the chief electrolytes but also essential for the nervous systems, maintenance of fluid volume in the body, contractile mechanism of muscles, maintenance of correct rhythm of heart beat, clothing of blood(Shahnaz *et al*., 2003).

Table 2: Mineral in dried Roselle in mg/100g,

Metal	Value
Potassium	101.5±0.1
Sodium	72.1±0.1
Magnesium	100.7±0.4
Calcium	14.8±0.6
Iron	8.5±0.3
Manganese	10.8±0.1
Copper	3.6±0.1
Zinc	0.2±0.0
Phosphorus	35.3±0.1

Values are presented as means±SD

3.3 Vitamin Determination

HPLC determination of water soluble vitamins (WSV) is presented in Table 3. The vitamins that were relatively high include niacin, ascorbic acid and pyridoxine as analyzed at a wavelength of 261nm, 265nm and 324nm respectively. Thiamin, riboflavin, panthothenic acid and folic acid also were present in appreciable amounts. However, there was 25-30% reduction in vitamins upon drying the roselle calyces this because vitamins are labile and degrade upon exposure to light, oxidation and thermal processes. Roselle calyces are relatively stable in vitamin B_6, B_3 and ascorbic acid retention in comparison to conventional fruits and vegetables.

Table 3: Water soluble vitamins in fresh and dried calyces of roselle before processing

Constituent vitamins	*Calyces (fresh)mg/100g*	Calyces (Dried)mg/100g
Niacin	3.765	2.644
Thiamin	0.177	0.123
Riboflavin	0.277	0.194
Panthothenic	0.324	0.227
Folic acid	0.122	0.092
Ascorbic acid	6.701	4.690
Pyridoxine	1.546	1.080

3.4 Bioactive Properties

The quality and bioactive properties of product before and after pasteurization and storage for 90 days are shown in Table 5.

Pasteurization and storage conditions significantly effected the total phenolic content (TPC) and Inhibition capacity (EC_{50}) of the product. Storage at 27^0C for 90 days significantly effected on the reduction of TPC. The antioxidant activity expressed as EC_{50} of the product was less in the activity compared to that at cold storage. The combination of organic acids present and other bioactive components could have the influence on the ability to scavenge for the radical. This study suggested that storage at 5 ^{0}C provided greater retention in bioactive properties of products compared to storage at 27^0C.

Table 5: Quality and bioactive properties of Roselle extract product before and after pasteurization and storage at 5°C and 27°C for 90 days

Quality and bioactive properties	Before pasteurization	After pasteurization	Storage for 90 days	
			5^0C	27^0C
pH	3.88±0.00^b	3.42±0.01^a	3.45±0.01^a	3.45±0.01^a
Total acidity(as malic acid)	2.24±0.00^a	2.24±0.03^a	2.23±0.04^a	2.25±0.04^a
Total phenolic content (mg) gallic acid/g extract)	6.06±0.18^a	5.82±0.01^a	3.3±0.41^b	2.58±0.43^c
Tannins (Mg/g)	2.26	3.21	4.17	4.07
EC 50 ug/ml	230.01±2.40^d	235.34±0.79^c	359.96±0.89	390.63±4.75^a

NB: Means ± standard deviation in each row with the same letters are not significantly different ($p > 0.05$) EC50: The concentration of dried Roselle extract (µg**/**ml) needed for 50% decreasing in the initial DPPH concentration.

There was decrease in pH after pasteurization and during storage. Similarly there was a decrease in total acidity. Theres a connection between pH and antioxidant activity. According to Azizah *et al,* (1999) the value of the pH affects antioxidant activity of products, as it has an effect on the type of compounds extracted from the raw material and their changes during heating or storage.

The ability to inhibit radical oxidation was demonstrated by roselle at various levels of concentrations as presented in Figure 1, at low concentration, inhibition was almost maximum at 100% decreasing gradually to less than 5% at 5mg/ml. As compared to the ascorbic acid Radical Scavenging capacity (RSC), it suggested the potential to offer antioxidant activities in comparison to ascorbic acid. As noted earlier, this is because of the bioactive components in roselle particularly anthocyanins.

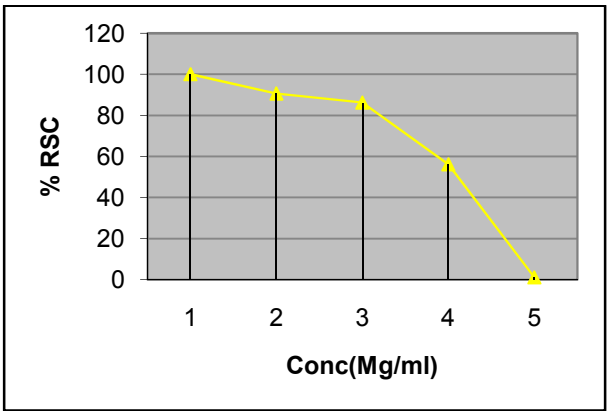


Figure 1: Percentage inhibition of roselle as depicted by the absorbance values at 517nm using UV-visible spectrophotometer

3.5 Total Phenolic Content (TPC)

Total phenolic content (TPC) in Roselle was measured by Folin Ciocalteu method and compared with their DPPH Radical Scavenging Capacity. As expected, they showed a close relationship (0.95) . The TPC and DPPH RSC of Roselle was high because of bioactive composition. There was direct correlation between Gallic acid concentration and spectrophotometer absorbance at 760 nm with a gradient of 0.7936 and correlation coefficient (R^2) of 0.9857 as shown in Figure 2. The sample readings generally increased with increase in temperature 51.7mg/g,62.5mg/g and 73.58mg/g of dry matter for 60^0C, 80^0C,100^0C respectively. Gansch (2009) tested TPC in Raspberry cultivars and ranged from 342.0 to 875.3 mg of GAE/100g of fresh weights. The relatively lower levels of TPC in *Hibiscus sabdariffa* could be attributed to the type of food matrix; roselle is a flower while raspberry is a fruit. Fruits are more concentrated in phenolics.

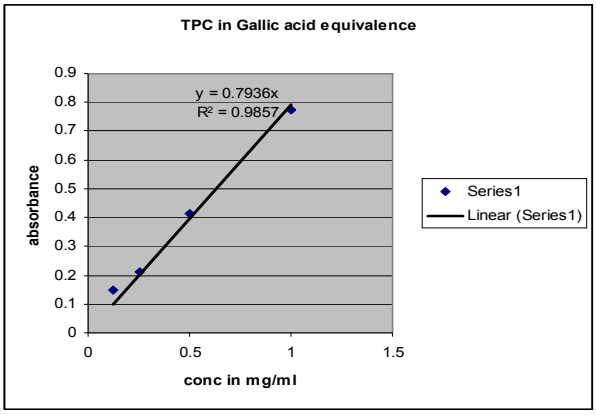


Figure 2: Plot for GAE versus absorbance at UV-V Spectrophotometer at a wavelength of 760 nm

3.6 Indices for Polymeric Colour

The products developed were monitored for a period of 60 days in terms of color changes. Figure 3 shows how the monomeric color of roselle drink changed in a period of two months as depicted by the calculated hue (h*) angle, i.e., arctan (b*/a*). The intensity of the pigment degradation was depicted by plotting the chroma(c*) calculated as $(a^{*2}+b^{*2})^{1/2}$ values against time as shown in Figure 4. The color changed gradually from red to dark red. This is anticipated because of the decrease in pH, copigmentation, oxidation and certainly the thermal processing of the products. Several studies have reported a logarithmic course of anthocyanin destruction with an arithmetic increase in

temperature (Drdak and Dancik 1990). Color degradation in roselle was as a result of anthocyanin degradation

For commercial production of roselle drink, processing time, temperature regimes will be critical to maintain color stability, quality and bioactive properties.

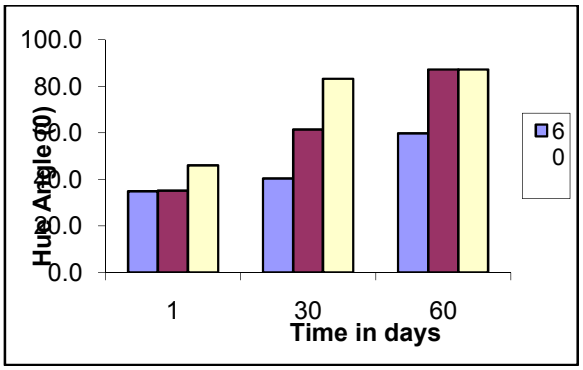


Figure 3: Hue angle of the Roselle drink at pasteurization temperature of 60,80 and 100 degrees as monitored for a period of 60 days

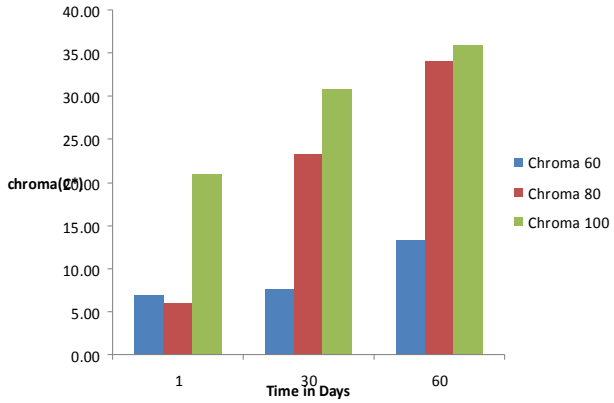


Figure 4: Chroma values for the Rosella drink at pasteurization temperatures of 60, 80 and 100 degrees as monitored over time

3.7 Sensory Analysis

After sensory analysis it was envisaged that pure rosella drink (RD) was most preferred, followed by ROD, RAD and then RMD. Tables 5, 6 and 7 present the sensory analysis of the various ratios for each product category ROD, RAD and RMD respectively. There were no significant differences in the formulation ratios within the product categories with respect to pure rosella drink (RD). However, appearance of the product was significant according to the panelists' responses, this was in agreement with the general knowledge about a consumers' judgment on the color of the product.

Generally all product categories were acceptable to consumers except RMD which was rated low; this could be due to the aroma and taste of the drink. The order of product acceptability based on 9-point hedonic scale was RD>ROD>RAD>RMD.

Table 5: Rosella orange drink (ROD) sensory Analysis based on 9-point hedonic scale

Products	*Appearance*	*Taste*	*Aroma*	*Consistency*	*Flavour*	*General*

code						*Acceptabilty*
100	7.7[a]	5.7[b]	6.7[a]	6.1[a]	6.3[a]	6.2[a]
300	6.2[b]	6.7[a]	6.5[a]	6.8[a]	6.2[a]	6.4[a]
301	6.9[ab]	6.7[a]	6.4[a]	6.4[a]	6.4[a]	6.8[a]
305	6.6[b]	7.1[a]	6.2[a]	6.4[a]	6.1[a]	6.7[a]

NB/=Means in columns with the same letters are not significantly different (p>0.05)
100=RD, 300=1:1,301=3:1,305=3:2.

Table 6: Sensory evaluation of Rosella apple flavored drink (RAD) at different rations with reference to pure rosella drink (RD=100)

Products code	*Appearance*	*Taste*	*Aroma*	*Consistency*	*Flavour*	*General Acceptabilty*
100	7.7[a]	6.5[a]	6.4[a]	6.7[a]	6.8[a]	6.9[a]
300	6.1[b]	6.9[a]	6.3[a]	6.0[a]	7.1[a]	6.9[a]
301	6.3[b]	6.7[a]	5.7[a]	5.3[a]	6.5[a]	6.8[a]
305	6.0[b]	6.8[a]	6.6[a]	6.1[a]	6.8[a]	6.3[a]

NB/=Means in columns with the same letters are not significantly different (p>0.05)
100=RD, 300=1:1,301=3:1,305=3:2.

Table 7: Rosella Mellon Drink (RMD) sensory Analysis based on 9-point Hedonic scale

Products code	*Appearance*	*Taste*	*Aroma*	*Consistency*	*Flavour*	*General Acceptability*
100	7.3[a]	6.0[a]	6.0[a]	5.7[a]	6.0[a]	5.8[a]
300	5.6[b]	4.0[a]	4.1[a]	4.8[a]	4.8[a]	4.8[a]
301	6.1[b]	4.5[a]	5.7[a]	4.9[a]	5.8[a]	5.3[a]
305	6.2[b]	4.8[a]	6.6[a]	5.0[a]	4.9[a]	5.2[a]

NB/=Means in columns with the same letters are not significantly different (p>0.05)
100=RD, 300=1:1,301=3:1,305=3:2.

4.0 Conclusions and Recommendations

The findings from this study suggest that the compounds in *Hibiscus sabdariffa* could potentially provide health benefits and support the ethnomedicinal use of roselle because of the depicted antioxidant activities. There was monomeric color degradation through polymerization as indicated by the hue and chroma indices of the processed products. From the foregoing processing temperature/time regimes & conditions of storage are critical in maintaining the bioactive compounds particularly total phenols. Roselle calyces could find applications in the food industry in the manufacture of a refreshing soft drink (Rosella drink-RD). Representative of Kenyan consumers rated highly rosella fruit flavored drinks RD>ROD>RAD. Preliminary research also shows that roselle could be applied in red wine and polymeric color development in food industry. To realize greater impact of the project however, cooperation at both institutional and national level is required in terms of resource commitment to upscale cultivation and utilization. The project is still in progress for conclusive outputs.

ACKNOWLEDGEMENTS

This project represents partial fulfillment for the Master of Science degree in Food Science and Technology and was supported by a grant from Kenya Industrial Research and Development Institute (KIRDI). Great tribute goes to Mrs Phyllis Ngunjiri of KIRDI for her relentless support, Prof. A.O. Makokha, Prof. S.N. Muhoho and Dr. E.G. Mamati for their invaluable ideas since inception of the project.

References

AOAC. (1995). Association of Official Analytical Chemists. Official Methods of Analysis, 16th ed. Washington DC,USA.

Ayoola, G. Sofidiya, A., Odukoya, T.O. and Coker, H. A. B. (2006)**.** Phytochemical Screening and Free Radical Scavenging Activity of Some Nigerian MedicinalPlants. *J Pharm Sci & Pharm Pract.,* **8**, pp 133-136.

Azizah, A. H., Ruslawati, N. M., Swee, T., (1999). Extraction and characterization of antioxidant from cocoa by-products. *Food Chem.,* **64**, pp 199-202.

Bravo, L. (1998). Polyphenols; Dietary Sources, Metabolism and Nutritional Significance.

Babalola, S.O., (2000). Chemical analysis of roselle leaf organs. *Mycologia*, **67**, pp 311-319.

Gansch, H., Weber, C. A. and Lee, C. (2009). Antioxidant Capacity and Phenolic Phytochemicals in Black Rapberries. *New York Fruit Quarterly.,*Vol. **17**(1).

Ina, K., Sakata, K., Tomita, L. and Isemura, M. (eds)(2002).Ten Components and their Function. Kawasaki, Japan.

Ihekoronye, A. I. and Ngoddy, P. O. (1985). Intergrated Food Science and Technology for the Tropics. Macmillan Press Ltd, London, England, pp 172-189.

Kim, D. O. and Lee, C. Y. (2002). HPLC Separation of Polyphenolics. Current Protocols in Food Analytical Chemistry. R. E. Wrolstad (Ed.In Chief), John Wiley and Sons, New York. 11.3:1-16.

Lee, H. S. (2002). Characterization of Major Anthocyanins and the Color of Red Fleshed Blood Orange (Citrus Sinensis). *J. Agric. Food Chem*., **50**, pp 2926-2930.

Mazza, Miniati (1993). Anthocyanins in Fruits, Vegetable And Grains, *CRC Press, Boca Raton*, Fl pp1-87.

Ojokoh, A. O., Adetuye, F. A., Akiuyosoye, E. and Oyetayo, V. O. (2003). Fermentation studies on roselle(Hibiscus sabderiffa) calyces neutralized with trona, in the proceeding of 16th annual conf. of Biotechnology society of Nigeria, pp, 90-92.

Shahnaz, A., Atiq-Ur-Rahman, M., Qadiraddin and X Shanim, Q. (2003). Elemental nalysis of Calendula of officinalis plant and its probable therapeutic roles in health. Pak. *J. Sci. Ind. Res.,* **46**: Edn, London. Pp 283-287.

Seeram, N. P., Schutziki, R., Chandra A. and Nair, M. G. (2002). Characterization, Quantification and Bioactivities in Cormus Species. *.Journal of Agricultural Food Chemistry,* **50**, pp 2519-2523.

Schippers, R. R., (2000). African Indigenous Vegetables an Overview of Cultivated Species. *National Resource Institute .Publisher Chatham*, UK. (Open Doc).

Watkins, C. (2008). The Market for Functional Foods. *Inform*, **6**, pp 378-380.

Wrolstad, R., Durst, R. W. and Lee, J. (2005). Tracking Color and Pigment Changes in Anthocyanin Products. *Trends in Food Science and Technology* **16**, pp 423-428.

BIODEGRADATION OF DIAZINON AND METHOMYL PESTICIDES BY WHITE ROT FUNGI FROM SELECTED HORTICULTURAL FARMS IN RIFT VALLEY AND CENTRAL PROVINCES, KENYA

W. O. Nyakundi, G. Magoma, J. Ochora and A. B. Nyende
Institute for Biotechnology research, Department of Biochemistry and Department of Botany Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: nyakundi.william@yahoo.com

Abstract
White rot fungi are robust organisms and are generally more tolerant to high concentrations of polluting chemicals than bacteria, they therefore present a powerful prospective tool in bioremediation. In this study, the potential for biodegradation of methomyl and diazinon by white rot fungi through enrichment and isolation of methomyl and diazinon biodegraders from horticultural soils was done. Five white rot fungal isolates WR1, WR2, WR4, WR9 and WR15 were cultured in a medium containing methomyl and diazinon as the only carbon source and incubated at 28^0C and monitored for biodegradation at intervals of 10 days for a period of 100 days. Using Gilson HPLC system with acetonitrile (75% sample: 25% acetonitrile) as the mobile phases. The biodegradation of methomyl and diazinon overtime using fungal isolate mixtures, took 59 days while for individual isolates, it took a maximum of 100 days to biodegrade the pesticides. These proofs that fungal mixtures in soil fasten the rate of biodegradation of pollutants compared to individual isolates. The pesticide methomyl was eluted at 4.9 minutes while the methomyl metabolite was eluted at 4.1 minutes. Diazinon was eluted at 11 minutes while the diazinon metabolites; diazoxon and oxypyrimidine were eluted at 2.3 and 2.6 minutes. The HPLC method used enabled the separation and quantification of the pesticides in an HPLC run-time of 15 min. Results indicated that after 100 days all the isolates managed to biodegrade the respective pesticides. The rate of mineralization or disappearance of a pesticide was proportional to the concentration of the pesticide. White rot fungi are advantageous over bacterial systems since these fungi can grow rapidly when supply of nutrients is low/limited.

Key words: White rot fungi, methomyl, diazinon, metabolite and biodegradation

1.0 Introduction

One of the major environmental problems facing the world today is the contamination of soil, water, and air by toxic chemicals. Eighty billion pounds of hazardous organopollutants are produced annually in agricultural farms and only 10% of these are disposed of safely (Reddy and Mathew, 2001). Certain hazardous compounds, such as methomyl and diazinon, are persistent in the environment and are known to have carcinogenic and/or mutanogenic effects. It can cost up to approximately $1 trillion to decontaminate toxic waste sites in the agricultural farms using traditional waste disposal methods such as incineration and land filling (Reddy and Mathew, 2001). Due to the magnitude of this problem and the lack of a reasonable solution, a rapid, cost-effective, ecologically responsible method of cleanup is greatly needed. One growing mechanism of decontamination that may fit these requirements is bioremediation. Utilizing microorganisms to degrade toxic organopollutants is an efficient, economical approach that has been successful in laboratory studies. Interest in bio-remediation as an alternative approach to clean-up has increased. Research on biodegradation has demonstrated the potential of white-rot fungi to degrade PAH (Boopathy, 2000).

Diazinon is found in all environmental compartments and given adequate time, it will be degraded by abiotic and biotic processes so that the parent compound is not persistent. Degradation products of diazinon include diazoxon and oxypyrimidine (Desaint *et al*., 2000). Oxypyrimidine is the main soil and water degradate of diazinon. Diazinon can be converted to diazoxon in the atmosphere via ultraviolet (Sethunathan, 1972). Diazinon released to surface waters or soil is subject to volatilization, photolysis, hydrolysis, and biodegradation. Diazinon has a relatively short half-life in water, ranging from 70 hours to 12 weeks depending on pH, temperature, and sunlight as well as the presence of microorganisms while in soil it's influenced by the pH conditions in the soil and the soil type (Sethunathan, 1972). In agricultural soils, methomyl is rapidly mineralized to carbon dioxide. No other degradation compound is observed in soil in significant amounts (Strathman *et al*., 2001). Methomyl oxime is a minor transient degradation product observed at a maximum of 2.9% of applied active ingredient. Methomyl does not leave any significant residues in soil after application (Tomlin, 2003).

White rot fungi is a physiological grouping of fungi that can degrade lignin. Four main genera of white rot fungi have shown potential for bioremediation: *Phanerochaete, Trametes, Bjerkandera*, and *Pleurotus* (Hestbjerg *et al*, 2003). These fungi cannot use lignin as a source of energy, however, and instead require substrates such as cellulose or other carbon sources. Thus, carbon sources such as corncobs, straw, and sawdust can be easily used to enhance degradation rates by these organisms at polluted sites. Also, the branching, filamentous mode of fungal growth allows for more efficient colonization and exploration of contaminated soil. The main mechanism of biodegradation employed by this group of fungi, however, is the lignin degradation system of enzymes. These extracellular lignin modifying enzymes (LMEs) have very low substrate specificity so they are able to mineralize a wide range of highly recalcitrant organopollutants that are structurally similar to lignin (Cajthaml *et al*, 2002; Mansur *et al*, 2003; Pointing, 2003, Veignie, 2004). The three main LMEs are lignin peroxidase, Mn-dependent peroxidase, and laccase. All three of these enzyme groups are stimulated by nutrient limitation (Mansur *et al*, 2003; Aust *et al,* 2004).

The mechanisms for the clean up of pesticides in soil such as chemical treatment, volatilization and incineration have met public opposition, because of problems such as large volumes of acids and alkalis which are produced and subsequently must be disposed off, also the potentially toxic emissions and the elevated economic costs. Overall, most of these physical-chemical cleaning technologies are expensive but inefficient. These clean-up methods do not suit large farms since only small soil samples are required and they are done in the laboratories and hence require a lot of resources (Kearney, 1998; Nerud *et al.*, 2003) because the contaminated soil has to be excavated at

a site and moved to a storage area where it can be processed. Due to environmental concerns associated with the accumulation of pesticides in food products and water supplies there is a great need to develop safe, convenient and economically feasible methods for pesticide remediation (Zhang and Quiao, 2002). For this reason several biological techniques involving biodegradation of organic compounds by microorganisms like bacteria and fungi (white rot fungi) have been developed (Schoefs *et al.*, 2004).

Expansion and intensification of agricultural and industrial activities in recent decades has led to pollution of soil and groundwater with pesticides and many treatment processes have been developed to reduce the environmental impacts of this contamination. In contaminated soils, microorganisms are more commonly found in mixtures. Very few studies have examined the degradation of pesticides using mixtures of microorganisms in soils. Moreover, there are hardly any studies on the use of mixtures of white rot fungi to clean-up pesticides.

The full potential of biodegradation by white-rot fungi has not been fully investigated for field soils. The objectives of this work were to evaluate the ability of selected white-rot fungi (WR1, WR2, WR4, WR9 and WR15) to degrade Methomyl and Diazinon. All possible combinations of these white rot fungi were also investigated to determine whether the use of fungal consortia could promote enhanced degradation. Experiments were designed so that the results obtained reflected not only differences in degradation potential, but also those related to speed and extent of fungal growth on the organic substrate, tolerance to high levels of methomyl and diazinon. This paper will review the research thus far on the potential use of microorganisms (especially white-rot fungi) in degrading some of the top pollutants (methomyl and diazinon).

2.0 Materials and Methods

2.1 Chemicals

Diazinon and methomyl were purchased from Sigma-Aldrich Chemical Company. All other chemicals, bacterial media and reagents were purchased from Oxoid limited- England, Scharlau Chemie- South Africa, Himedia laboratories and PVT limited- India. All the solvents and chemicals were high purity grade reagents.

2.2 Soil Particle Washing and Plating

Soil cores of 2.5 cm diameter were taken to 5 cm depth after the litter layer was removed. Sampling was done using stratified random sampling method from two regions in Kenya; Rift-valley region and Mt. Kenya region. The geographical regions formed four strata and from each region, two plots were identified by simple randomization. Similar sampling was done 100 m away from the farms to act as controls. Samples were stored at 4^0C until processing, in most cases within 2 days. Approximately 5 g fresh weight (2.5 to 4.5 g dry weight) of each soil sample was added to 500 ml of sterile 0.1% (wt/vol) sodium pyrophosphate in 1-liter mason jars. These were gently shaken end-to-end on a platform shaker for 1 h at 48^oC to disperse soil clumps and colloids (Bingle and paul, 1986). The entire suspension was poured through stacked 20 cm diameter soil sieves (Newark wire cloth) of 250 mm (no. 60) and 53 mm (no. 270) mesh and rinsed through with a brief shower of cold tap water. Particles remaining on the 53mm mesh sieve were then washed for 5 min under this shower at a flow rate of approximately 20 liters/min. Remaining solids were collected at one edge of the sieve, and the sieve was tilted to separate suspended organic particles from settled mineral particles. One milliliter of a dense suspension of the organic particles was picked up in a sterile broad-bore pipette tip (Gilson P-1000). This suspension was diluted in sterile distilled water to 10^{-2}, and 0.4 ml of this dilution was spread onto each of 20 petri dishes of lignin-guaiacol-benomyl agar. Sieves were rinsed with water and sterilized in 70% ethanol between samples (Bingle and paul, 1986).

2.3 Composition of the Media

Soil particle-washing technique (Bååth, 1988, Bills and Polishook, 1994, Bissett and Widden, 1972) was used to remove spores of ascomycetous and zygomycetous molds, and plated the washed particles on a medium made selective for basidiomycetes by the incorporation of benomyl as described by Bååth (1988) (Table 1). In addition to benomyl, the medium contained lignin, to encourage selection of ligninolytic fungi, and guaiacol, which acts as a colorimetric indicator of the lignin-modifying enzymes laccase or peroxidases (Arora and Sandhu, 1985). All chemicals were obtained from Sigma Chemical Co., St. Louis, Mo. (Greg *et al*., 1996 and Domsch *et al*., 1980).

Table 1: Composition of media for isolation of white rot fungi as described by Bååth, 1988

Ingredients	*g/l*	*Ml/l*	*Concentration*	*Mg/l*
KH_2PO4	0.5			
$MgSO_4.7H_2O$	0.2			
NH_4NO_3	0.1			
KCl	0.1			
$FeSO_4.7H_2O$	0.02			
$Ca(NO3)_2.4H_2O$	0.05			
Malt extract	2			
Agar	15			
KOH		5	1M	
Guaiacol		0.4		
Indulin AT	1			
Dioxane		10		
Chloramphenicol	0.25			
Benomyl				4
Acetone-70% ethanol		2		

2.4 Isolation and Identification of White Rot Fungi

After one day of inoculation, the Petri dishes were packed in their plastic sleeves and incubated at 28^0C for 2 weeks before making isolations. At this time, plates were scanned for colonies that caused reddening of the guaiacol by the action of laccase or peroxidase. These colonies were examined microscopically (at x40 and x100) for the presence of conidia or clamp connections. Plates were screened again after 4 and 6 weeks. At each screening, colonies of putative basidiomycetes were isolated onto malt-yeast agar containing chloramphenicol and tetracycline. In order to identify putative white rot fungi isolates, cultures were considered to be basidiomycetes if they showed clamp connections at septa or positive staining with diazonium blue B ($ZnCl_2$ complex of tetrazotized *o*-dianisidine; Sigma) (Summerbell, 1985).

2.4.1 Minimal Mineral Media for Methomyl and Diazinon Liquid Cultures

Mineral medium MMN (mineral medium without nitrogen and carbon) was derived from mineral medium MMO (Stainer *et al.,* 1966) by elimination of all nitrogen. MMN medium contained 1,419.6 mg of Na_2HPO_4, 1,360.9 mg of KH_2PO_4, 98.5 mg of $MgSO_4$, 5.88 mg of $CaCl_2 \cdot 2H_2O$, 1.16 mg of H_3BO_4, 2.78 mg of $FeSO_4 \cdot 7H_2O$, 1.15 mg of $ZnSO_4 \cdot 7H_2O$, 1.69 mg of $MnSO_4 \cdot H_2O$, 0.38 mg of $CuSO_4 \cdot 5H_2O$, 0.24 mg of $CoCl_2 \cdot 6H_2O$, 0.10 mg of MoO_3, and 3.2 mg of EDTA in 1 liter of distilled water. The liquid mineral medium was supplemented with 50 ppm and 12.5 ppm of methomyl and diazinon respectively (Fluka AG Chemische Fabrik, Buchs, Switzerland).

2.4.2 Isolation of White Rot Fungi Using Methomyl and Diazinon as the Only Sole Carbon Source

Soil samples (5 g) contaminated with diazinon and methomyl were used to inoculate baffled Erlen–meyer flasks containing 50 ml mineral medium supplemented with diazinon and methomyl as sole

carbon source. Flasks were incubated at 28°C with shaking (1200 rpm) in the dark. After approximately 7 days samples from these cultures were spread-plated on mineral salts agar containing 12 ppm diazinon and 2M methomyl. Isolates that showed fast growth on plates were selected for further analysis.

2.5 White Rot Fungi Isolates Growth in Liquid Culture

Isolates were precultured in baffled erlenmeyer flasks containing mineral salts medium with the above mentioned concentrations of pesticides. Flasks were incubated at 30^{0}Cwith shaking (1200 rpm) in the dark. Growth was monitored as changes in OD600 (Shimadzu, Japan). When growth had occurred, the flasks contents were centrifuged the cell pellets were then washed in fresh sterile medium 4 times before addition to mineral medium and the pesticides. At periodic intervals 2.5 ml samples were removed and cell growth monitored. Two controls were performed: uninoculated medium with the pesticides and medium without the pesticides inoculated with the isolates (George *et al*., 2005).

2.6 HPLC Analysis of Pesticide Degradation

The degradation of the pesticides was monitored by high performance liquid chromatography. (Shimadzu HPLC class *VP* series) with two LC – 10 AT *VP* pumps (Shimadzu), variable wavelength UV detector SPD10*VP* (Shimadzu), CTO-IOAS *VP* column oven (Shimadzu), (Shimadzu) and a reverse phase C-18 column,250 x 4.6mm,fitted with a C-18 silica reverse phase guard column was used. (Fisher Scientific, Fairlawn, N.J) The HPLC system was equipped with software class *VP* series ss420x (Shimadzu). The mobile phase components acetonitrile and degassed water were pumped from the solvent reservoir to the column at a flow rate 1 mL/min. The column temperature was maintained at 27^0 C. 20 µL of sample was injected using Rheodyne syringe (Model 7202, Hamilton). These compounds were identified by their retention times and peaks corresponding to reference standards.

3.0 Results

3.1 Morphological Characterization of White Rot Fungal Isolates

Figure 1a shows a red color at the back side of a plate containing the medium lignin guaiacol benomyl agar with low concentration of lignin around the point of growth, while figure 1b shows the front side of the same plate which is characterized by the growth of mycelia. Figure 1c shows a plate with high concentration of lignin hence the darkening color.

(a)

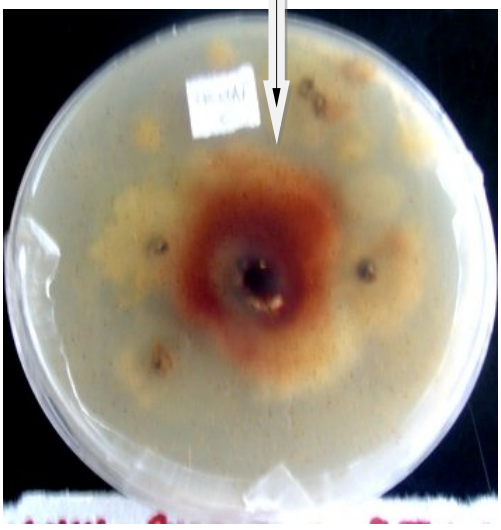


Figure 1a: Back side of plate showing isolates growing on Lignin Guaiacol Benomyl agar with low

(b)

Figure 1b: Front side of plate showing isolates growing on Lignin Guaiacol Benomyl

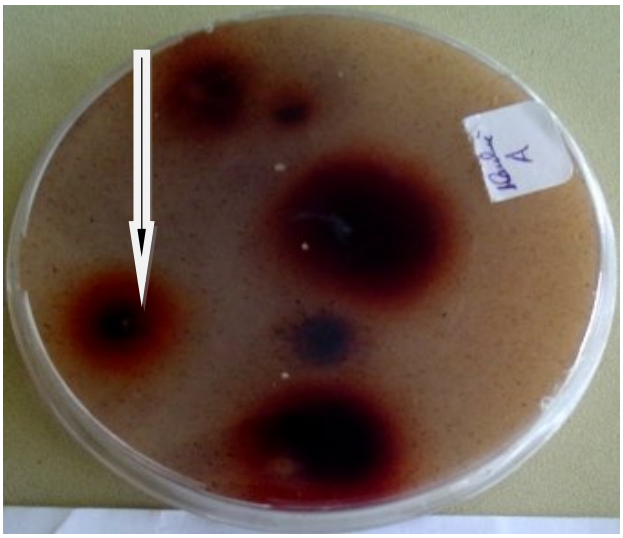
(c) 

Figure 1c: Back side of plate showing isolates growing on Lignin Guaiacol Benomyl agar with high concentration of lignin

Figure 1 a, b and c. Isolates producing laccase or peroxidase on lignin-guaiacol-benomyl agar are readily located by the dark and bright red zone beneath their colonies as indicated by the arrows.

3.2 Microscopic Characterization of White Rot Fungal Isolates

Figure 2 shows clamp connections (arrows) as seen under the microscope at x100 objective lens.

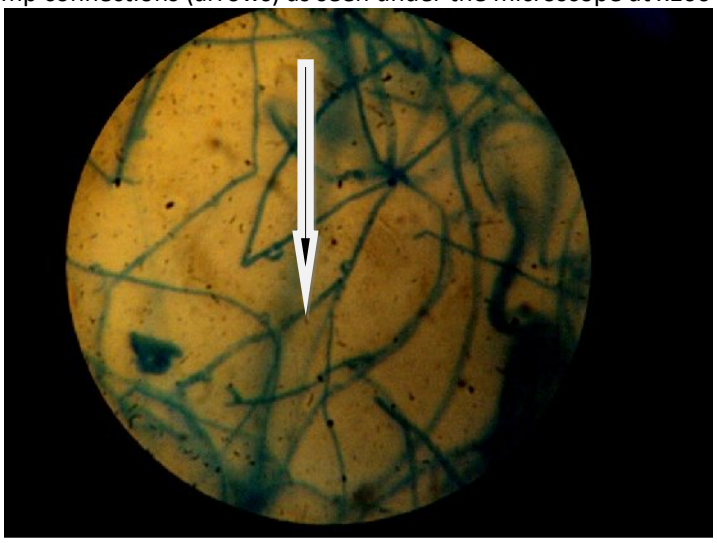


Figure 2: Isolate showing clamp connections (arrows) as seen under the microscope at x100 objective lense

Figure 3 below shows fruiting body as seen under the microscope at x100 objective lense.

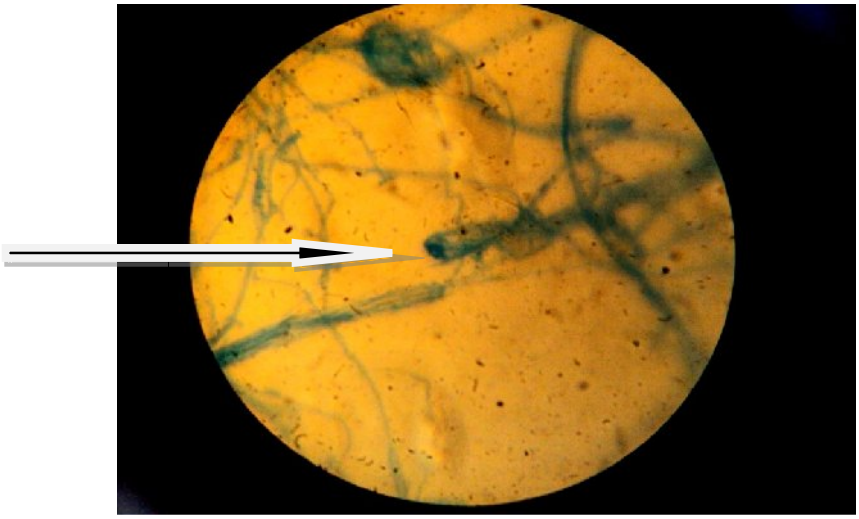


Figure 3: White rot fungi isolate showing fruiting body (arrow) as seen under x100 objective lense

Figure 3 showing white rot fungi isolate fruiting body (arrow) as seen under the microscope at x100 objective lense.

3.3 Biodegradation Profiles of Methomyl by White Rot Fungi

Figure 4a and b**.** Shows profiles of mineral salts (0 days) and methomyl pesticide (10 days) after a hplc run time of 10 minutes respectively.

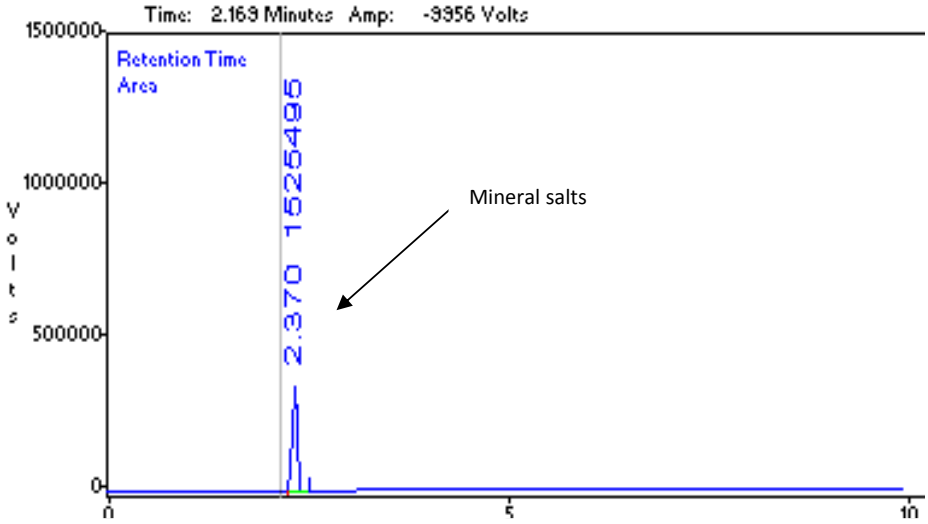


Figure 4a: Profile of Minimal mineral salt medium run in the Hplc at a retention time of 2.3 minutes (1525495) at a flow rate of 1ml/min for a run time of 10 minutes after 0 days

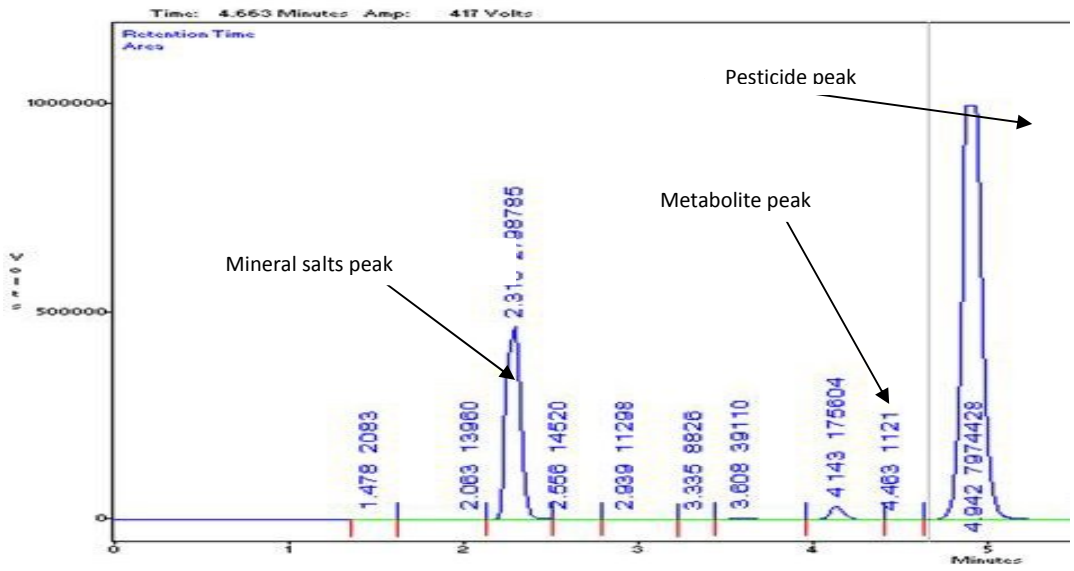


Figure 4b: Methomyl profile showing mineral salt peak at retention time of 2.3 minutes (2798785), metabolite peak at retention time 4.1 minutes (175604) and pesticide peak with a retention time of 4.9 minutes (7974428) after a hplc runtime of 10 minutes for 10 day old WR2 culture of white rot fungi

Figure 4c. Shows biodegradation profiles of a mixture of white rot fungi isolate WR2 and WR9 in methomyl pesticide (10 days old) after a hplc run time of 10 minutes.

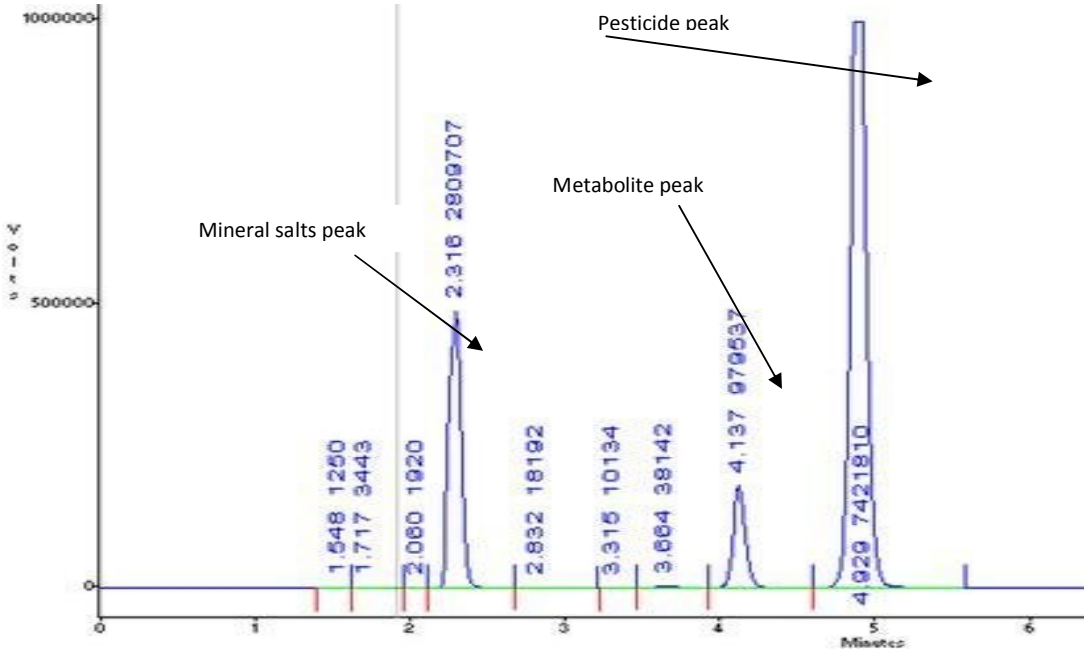


Figure 4c: Methomyl profile showing mineral salt peak at retention time of 2.3 minutes (2809707), metabolite peak at retention time 4.1 minutes (979537) and pesticide peak with a retention time of 4.9 minutes (7421810) after a hplc runtime of 10 minutes for 10 day old

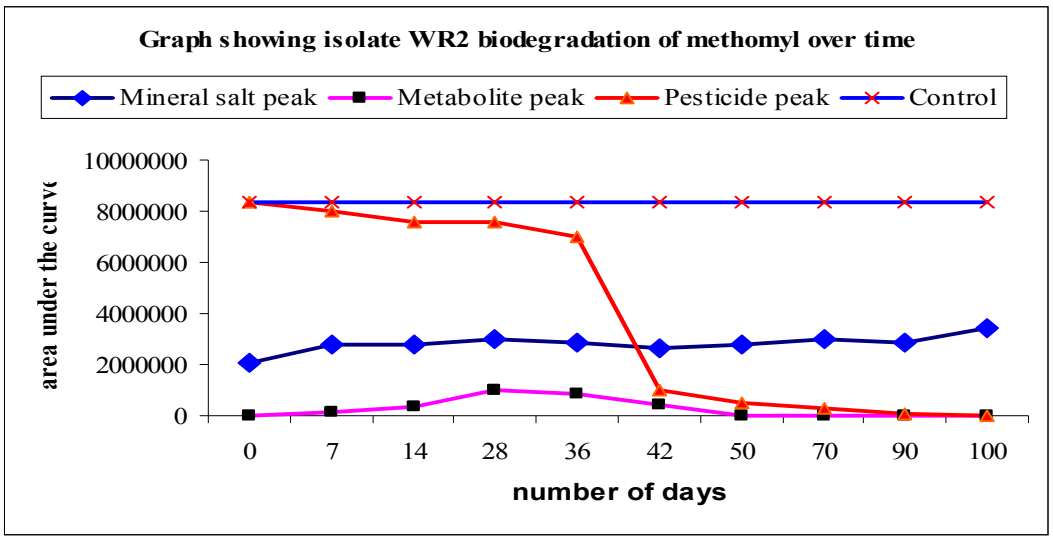


Figure 5a: Methomyl biodegradation profile of isolate WR2 over a period of 100 days

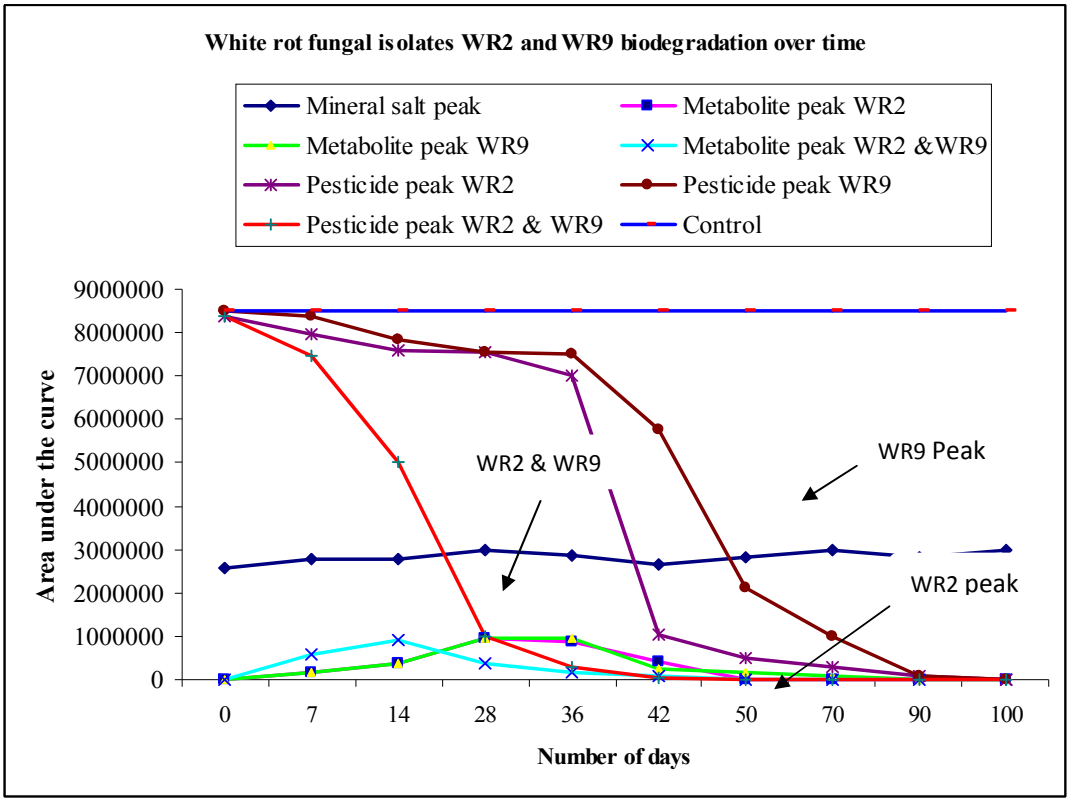


Figure 5b: Methomyl biodegradation profile of a mixture of isolate WR2 & WR9 over a period of time

3

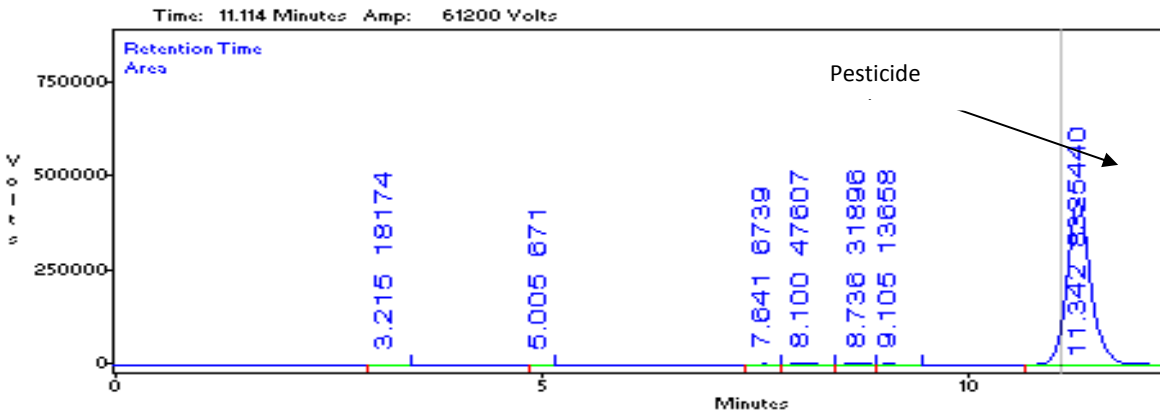


Figure 6a: Profile showing peak of diazinon pesticide with time retention of 11 minutes (8325440)

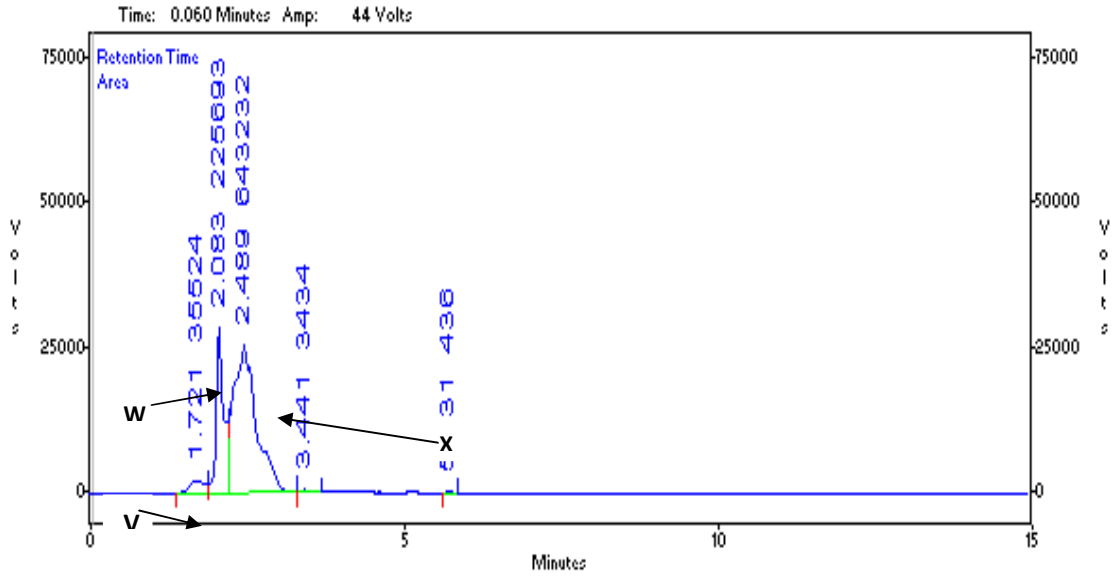


Figure 6b: Diazinon mineral salt peak V, W & X at retention time 1.7 minutes (35524), 2.0 minutes (225693) and 2.4 minutes (643232) respectively

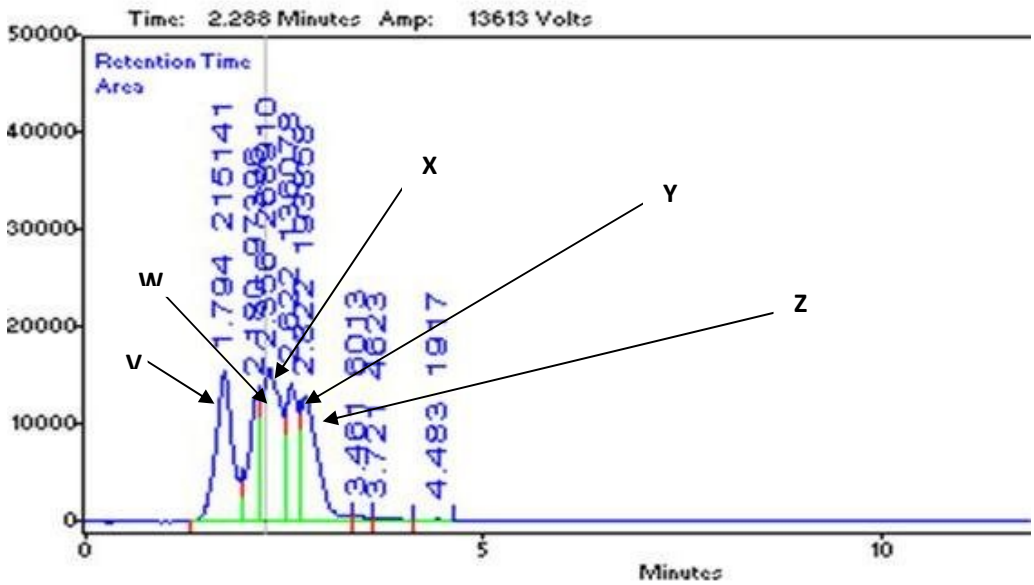


Figure 6c: Profile showing complete biodegradation of the pesticide diazinon by white rot fungi isolate WR15 after 80 days. The mineral salt peaks are V at retention time 1.7 minutes (215141), W retention time 2.1minutes (97396), X retention time 2.3minutes (268910) while the metabolite peaks are; Y retention time 2.6minutes (136078) and Z retention time 2.8 minutes (193858)

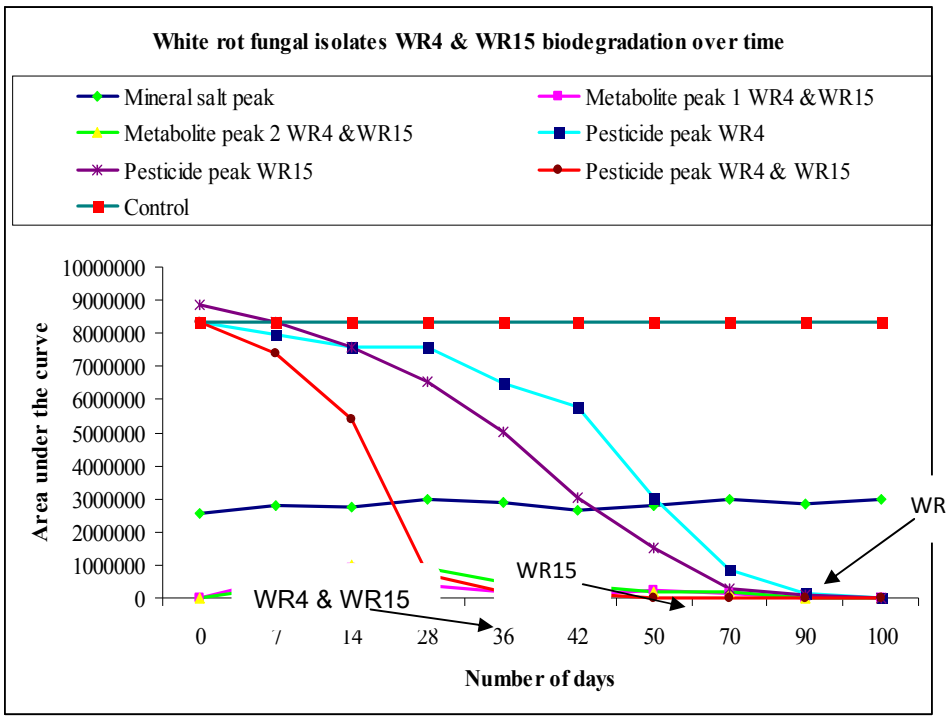


Figure 6d: Diazinon biodegradation profile of white rot fungi isolates WR4 &WR15 over a period of 57 days

4.0 Discussion

In these study, two major findings in biodegradation of contaminated soils namely; the ability of white-rot fungi in Methomyl and Diazinon degradation and the use fungal consortia in promotion of enhanced degradation were reported. A total of sixteen white rot fungi were isolated with ease from soils with history of diazinon and methomyl pesticide contamination. This finding is important as it suggests a possible use of the white rot fungi in metabolizing of methomyl and diazinon. This finding agrees with the findings of Sasek (2003) who reported the ability of a white rot fungus *Phanerochaete chrysosporium* to metabolize a number of various important environmental pollutants. The need to remediate contaminated sites has led to the development of new technologies that emphasize the destruction of the contaminants rather than the conventional approach of disposal (Boopathy, 2000), hence possible use of white rot fungi may be an important factor in this solution.

The significant fungal growth rates observed with five isolates (WR1, WR2, WR4, WR9 and WR15), after a series of screening in biodegradation studies, is another important finding in this study as it shows an essential component of these fungi in bioremediation. The study of fungal growth rates is very important for extrapolation of the potential colonization capacity in the field as it provides a good indication of the speed at which a fungus is able to colonize and transverse a substrate. Growth rates may also indicate which species may be dominant over a particular substrate; fast growing species have an advantage over slower species as they can reach and utilize resources before their competitors (Magan and Lacey, 1984; Marin *et al*., 1998a; Marin *et al*., 1998b). Therefore, better growth could help the introduced fungi to overcome competition from indigenous soil microorganisms (Singleton, 2001). Since mixtures of microorganisms exist in soil (Aust, 2003), they compete for sources of carbon for their survival by utilizing the available substrates ending up in toxic or less toxic metabolites as by products (Reddy and Mathew, 2001).

The results in Figure 4 show that methomyl pesticide at a wavelength of 235nm, it is detected at an hplc runtime of 4.9 minutes while its metabolite at 4.1 minutes. According to Strathmann (2001), soil studies demonstrate that methomyl degrades rapidly in aerobic soil to yield carbon dioxide and biologically unavailable and unextractable residue. The minor transient degradation product of methomyl, methomyl oxime, degrades even more rapidly. Strathmann (2001) agrees with our results which show that the metabolite peak at 4.1 minutes disappeared over time before degradation of methomyl was achieved. Veignie (2004) stated that microorganisms in soil utilize metabolites produced during degradation by other organisms. This was evident when two fungal isolates were mixed, hence accelerating the rate of disappearance of the pesticides as shown in figure 5a & 6d where degradation took 100 days to be complete for a single isolate. However, when the isolates were mixed (figure 5b and 6d), degradation took half (50-57 days) the time taken by a single isolate. This finding shows that degradation is much quicker and faster when microbes are used in mixtures compared to when they are used individually.

In the results diazinon at a wavelength of 254nm, was detected at a retention time of 11 minutes and metabolites at 2.6 and 2.8 minutes as shown in figure 6d and 6c. This agrees with the work of Sethunathan (1972) who stated that “Degradation products of diazinon include diazoxon and oxypyrimidine”. From the results, the two metabolite peaks represent both diazoxon and oxypyrimidine. According to Suet (1971), diazinon released to surface waters or soil is subject to volatilization, photolysis, hydrolysis, and biodegradation. In the study, the area under the curve of the pesticide peak for the control reduced slightly, an observation that would easily be attributed to photolysis. It is important to note that biodegradation, primarily under aerobic conditions, is a major fate process for diazinon associated with water and soil, whereas hydrolysis is an important mechanism for degradation, particularly at low pH in water and soil (Suet, 1971).

We conclude that results from field studies, however basic, are extremely valuable for directing future research and for demonstrating complications that arise when bioremediation is applied at a large scale. The base of knowledge on bioremediation capabilities of white rot fungi is growing rapidly from laboratory studies so the next step is to utilize this pool of information in an exploratory way in the field. Considering the serious consequences on human and ecosystem health that some of the above- mentioned contaminants create, the sooner we find a set of preliminary sustainable solutions, the better. White rot fungi may play a large role in this search, providing an environmentally- friendly, economical approach that we are really just beginning to understand.

5.0 Conclusion

The findings of this study and other related studies on biodegradation suggest that white rot fungi have potential for use in the remediation of soils contaminated with hazardous compounds, including diazinon and methomyl. However, before the use of these fungi can be considered a viable alternative, the nature, toxicity, and stability of the soil-bound products must be elucidated under a variety of conditions. Selected white rot fungi could prove valuable in on-farm pesticide bioremediation systems.

6.0 Recommendations

Research should be concentrated to develop economical but effective microbial processes for treatment of industrial effluents containing these pesticides and taking them to field. More understanding is required to improve the accurate prediction of the environmental fate of pesticides. In order to reduce the problem of enhanced degradation of pesticides in soil, the rotation of crops and of pesticides is recommended. These approaches may lead to the reduced use of pesticides. Selected microbial cultures are now available to set up industrial processes for decontamination of effluents, agricultural wastes and dump sites. Such an approach is likely to be efficient and cost-effective for many problems. Genetically modified microorganisms can provide improved activity which should prove useful in large-scale applications of microbial degradation to environmental problems. However, it is essential that such microorganisms are thoroughly evaluated for safety before release into the environment.

Acknowledgement

The authors are grateful to the Research production and extension department, Jomo Kenyatta University of agriculture and technology Kenya for the research grant. Rotich, Philip and Kevin are also acknowledged for their assistance in the laboratory.

References

Arora, D. S., and Sandhu, D. K. (1985). Survey of some Indian soils for laccase producing fungi and their lignin degrading ability. *Proc. Indian Acad. Sci. Plant Sci.,* **94**, pp 567–574.

Aust, S. D. P. R. Swaner Stahl, J. D. (2003). Detoxification and metabolism of chemicals by white-rot fungi. *Pesticide decontamination and detoxification,* J. J. P. C. Zhu S. D. Aust A. T. Lemley Gan 3-14. Washington, D.C.: Oxford University Press.

Bååth, E. 1988. A critical examination of the soil washing technique with special reference to the size of the soil particles. *Can. J. Bot.,* **66**, pp 1566–1569.

Bills, G. F., and Polishook, J. D. (1994). Abundance and diversity of microfungi in leaf litter of a lowland rain forest in Costa Rica. Mycologia, **86**, pp 187–198.

Bingle, W. H., and Paul, E. A. (1986). A method for separating fungal hyphae from soil. *Can. J. Microbiol*., **32**, pp 62–66.

Bissett, J., and Widden, P. (1972). An automatic, multichamber soil-washing apparatus for removing fungal spores from soil. *Can. J. Microbiol.,* **18**, pp 1399–1404.

Boopathy, R. (2000). Bioremediation of explosives contaminated soil. *International Biodeterioration and Biodegradation,* **46**, pp 29-36.

Cajthaml, T. M. Möder P. Kacer V. Šašek and Popp, P. (2002). Study of fungal degradation products of polycyclic aromatic hydrocarbons using gas chromatography with ion trap mass spectrometry detection. *Journal of Chromatography A* **974**, pp 213-22.

Desaint, Stéphane; Hartmann, Alain; Parekh, Nisha R. and Fournier, Jean-Claude. Genetic diversity of carbofuran-degrading soil bacteria. *FEMS Microbiology Ecology*, December 2000, vol. **34**(2), pp 173-180.

Domsch, K. H., W. Gams, and T.-H. Anderson. 1993. Compendium of soil fungi. IHW Verlag, Eching, Germany.

George M, Don J, Noel R, Ames T (2005). Bergey's Manual of Systematic Bacteriology, 2nd ed. Springer, New York, ISBN 0-387- 95040-0. pp. 359-361.

Getzin, L. W. (1967). Metabolism of diazinon and Zinophos in soils. *J. Econ. Entomol.* **60**, pp 505-8.

Hestbjerg, H. P. A Willumsen M. Christensen O. Andersen Jacobsen, C. S. (2003). Bioaugmentation of tar-contaminated soils under field conditions using *Pleurotus ostreatus* refuse from commercial mushroom production. *Environmental Toxicology and Chemistry,* **22** (4), pp 692-98.

Kearney P. and Wauchope R. (1998) Disposal options based on properties of pesticides in soil and water. **In**: Kearney P. and Roberts T. (Eds.) Pesticide remediation in soils and water. Wiley Series in Agrochemicals and Plant Protection.

Lau, K. L. Y. Y. Tsang and Chiu, S. W. (2003). Use of spent mushroom compost to bioremediate PAH-contaminated samples. *Chemosphere,* **52,** pp 1539-46.

Law, W. M. W. N., Lau, K. L., Lo, L. M., Wai Chiu, S. W. (2003). Removal of biocide pentachlorophenol in water system by the spent mushroom compost of Pleurotus pulmonarius. *Chemosphere,* **52**, pp 1531-37.

Levin, L. A. Viale A. Forchiassin (2003). Degradation of organic pollutants by the white rot basidiomycete *Trametes trogii*. *International Biodeterioration &Biodegradation* **52**, pp 1-5.

Mansur, M. M. E. Arias J. L. Copa-Patino M. Flärdh and González, A. E. (2003). The white-rot fungus *Pleurotus ostreatus* secretes laccase isozymes with different substrate specificities. *Mycologia,* **95**(6), pp 1013-20.

Mayer, A. M. and Staples, R. C. (2002). Laccase: new functions for an old enzyme. *Phytochemistry,* **60**, pp 551-65.

Mester, T. and Tien, M. (2000). Oxidation mechanism of ligninolytic enzymes involved in the degradation of environmental pollutants . *International Biodeterioration & Biodegradation,* **46**, pp 51-59.

Nerud F., Baldrian J., Gabriel J. and Ogbeifun D. (2003) Nonenzymic degradation and decolorization of recalcitrant compounds. In Sasek V. *et al*. (Eds.) The utilization of bioremediation to reduce soil contamination: Problems and solutions, pp. 29-48. Kluwer Academis Publishers.

Pointing, S. B. (2001). Feasibility of bioremediation by white-rot fungi. *Applied Microbiology Biotechnology,* **57**, pp 20-33.

Reddy C. A. and Mathew, Z. (2001). Bioremediation potential of white rot fungi *Fungi in bioremediation.* G. M. Gadd Cambridge, U.K.: Cambridge University Press.

Sasek (2003). Why mycoremediations have not yet come to practice. *In* Sasek V. *et al*. (Eds.) **In**: The utilization of bioremediation to reduce soil contamination: Problems and solutions, pp. 247- 76. Kluwer Academis Publishers.

Schoefs O., Perrier M. and Samson R. (2004). Estimation of contaminant depletion in unsaturated soils using a reduced-order biodegradation model and carbon dioxide measurement. *Applied Microbiology and Biotechnology*, **64**, pp 256-61.

Sethunathan, N., MacRae, 1. C. 1969. Persistence and biodegradation of diazinon in submerged soils. *J. Agric. Food Chem*., **17**, pp 221-25.

Sethunathan, N., Pathak, M. D. (1972). Increased biological hydrolysis of diazinon after repeated application in rice paddies. *J. Agric. Food Chem*., **20**, pp 586-89.

Strathmann, Timothy J. and Stone, Alan T. (2001). Reduction of the carbamate pesticides oxamyl and methomyl by dissolved FeII and CuI. *Environmental Science and Technology*, **35**(12), pp 2461-2469.

Suett, D. L. (1971). Persistence and degradation of chlorfenvinphos, diazinon, fonophos and phorate in soils and their uptake by carrots. *Pestic. Sci.,* **2**, pp 105-12.

Summerbell, R. C. (1985). The staining of filamentous fungi with diazonium blue B. *Mycologia,* **77**, pp 587–593.

Tomlin, Clive D.S. *The Pesticide Manual*. BCPC Publications.13th Ed. 2003. 1344 p. ISBN 978-1-90139613-

Veignie, E. C. Rafin P. Woisel, Cazier, F. (2004). Preliminary evidence of the role of hydrogen peroxide in the degradation of benzo[a]pyrene by a non-white rot fungus *Fusarium solani*. *Environmental Pollution,* **129**, pp 1-4.

Verdin, A. A. L-H. Sahraoui R. Durand. (2004). Degradation of benzo[a]pyrene by mitosporic fungi and extracellular oxidative enzymes. *International Biodeterioration and Biodegradation,* **53**, pp 65-70.

Zhang J. and Chiao C. (2002) Novel Approaches for remediation of pesticide pollutants. *International Journal Environment and Pollution*, **18**(5), pp 423-433.

SUB-THEME VIII

WATER, ENVIRONMENT AND CLIMATE CHANGE

HYDROLOGIC ANALYSIS OF MALEWA WATERSHED AS A BASIS FOR IMPLEMENTING PAYMENT FOR ENVIRONMENTAL SERVICES (PES)

L. P. Ogweno[1], J. M. Gathenya[2], and P. G. Home[3]
[1] Kenya Industrial Research and Development Institute, Nairobi, Kenya
[2,3]Department of Biomechanical and Environmental Engineering, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: ogwenop@gmail.com

Abstract
This paper investigates the hydrological effects of specific land use changes in Malewa catchment through the application of the Soil and Water Assessment Tool (SWAT) as a basis for implementing PES on a daily time step. The model's calibration efficiency is verified by comparing the simulated and observed discharge time series at the outlet of the watershed, where long series of hydrometrical data exist. The model is used to simulate the main components of the hydrologic cycle, in order to study the effects of land use changes. The model was calibrated and validated for the prediction of flow. Extensive continuous flow data over 10-year period from three locations within the basin were used for model calibration and validation. Sensitive model parameters were adjusted within their feasible ranges during calibration to minimize model prediction errors for daily and monthly flows. Water quality parameters (sediment, nitrogen and phosphorous loadings) were not available hence were not calibrated but the model default values were used after calibrating the flow data. At the main gauging station 2GB01; monthly calibration resulted in model prediction average flow within 19% of the measured average flow while the monthly Nash-Sutcliffe (ENS) measure was 0.58. Monthly validation results for 2GC05 and 2GB07 showed the model predicted average flow within 20% of the measured average flow with ENS of 0.58 and 0.61 respectively. Once the model was calibrated for flow, it was used to run scenario analyses for the selected target areas for PES implementation. A criterion was developed based on several parameters to select the target areas for PES implementation. Some of these parameters included annual rainfall, water yield, population density, water conflicts, and pressures on vegetation and water bodies. Based on the mentioned parameters, two areas were identified to be suitable for PES implementation. The two areas are within the upper catchment near GETA and Wanjohi areas. Four land-use scenarios were simulated in the selected headwater sub-basin areas to assess the impact of landuse change on Malewa hydrological regime. The deforestation scenario was the one that resulted in the greatest modification of total monthly runoff.

Key words: Hydrologic models, Soil and Water Assessment Tool, land use changes and PES

1.0 Introduction

Ecosystems provide a whole range of valuable environmental services, such as water services, biodiversity conservation or carbon sequestration. However, these services are usually lost or deteriorated since landowners often do not receive any compensation for providing these services and, therefore, they are ignored in decisions related to the land use (FAO, 2004). The concept of payment for environmental services (PES) is a promising solution to incorporating market based mechanisms in decisions related to land use, which has caused significant interest over the last years. However, putting theory into practice is not an easy task (Pagiola and Platais, 2003).

Often it is assumed that land use practices have significant impacts on water resources and affect the downstream population in the watershed (FAO, 2004). Payments by the downstream population to the upstream population for "hydrological services", such as a good quality of water, less sediments or a more regular flow regime are some of the mechanisms to internalize these impacts. However, there is much controversy on the direction and extent of such impacts, their influence in the relations between the different resource users in the watershed and the mechanisms to distribute costs and benefits among the various users. This calls for the need of a careful assessment and monitoring of land-water relations for the implementation of payment systems for environmental services in watersheds.

The effects of land use on water resources vary according to local conditions. The assessment is difficult due to large delays between cause and effect and the interference between anthropic and natural impacts caused by, e.g., climatic changes. These limitations make it difficult to draw general conclusions about the relations between land and water use in watersheds. However, some experiences show that land management impacts on watershed hydrology and sedimentation are observed more clearly in small-scale watersheds of about tens of square kilometers. Some land management effects on water quality can be observed also at larger scales. In recent years there has been an increasing trend to predict hydrologic changes brought about by land cover transformations in the tropics by robust models employing data obtained during relatively short but intensive measuring periods (Shuttleworth, 1990 and Institute of Hydrology, 1990).

Effective hydrological modeling of watersheds is an essential tool in the management of land degradation and its off-site impacts, such as those associated with salinity and nutrient problems. Various methods have been used in the past to model processes and responses in catchment hydrology. Catchment hydrology models can be considered crudely as either, physical, conceptual or empirical. Each of these modeling approaches suffers from certain inadequacies

1.2 Overview of the Study Area

Malewa basin lies between the two flanks of the Eastern or Gregory Rift Valley, with the Aberdares Mountains and Kinangop plateau on the east and the Mau Escarpment on the west. The Malewa basin is situated in the central Rift Valley, Naivasha District in Kenya about 100 km northwest from Nairobi (Figure 1). Its geographical position lies between 36°15’E-36°30’E longitude and 00°40’S-00°53’S latitude. The altitude ranges from 1900-3980m.a.m.s.l.

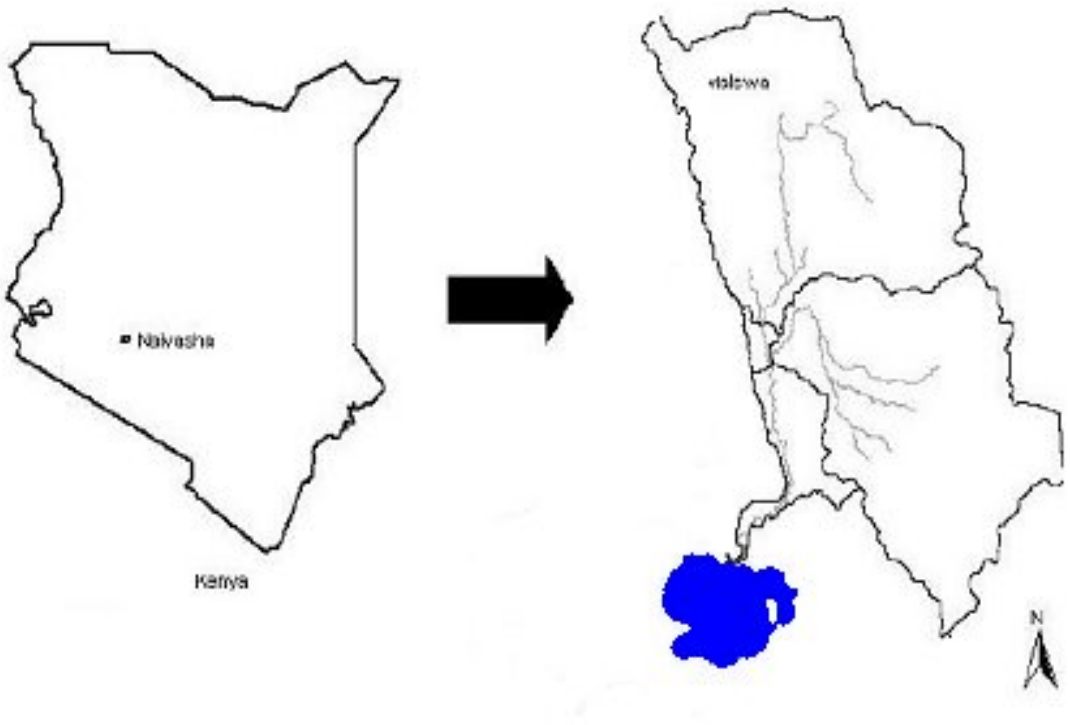
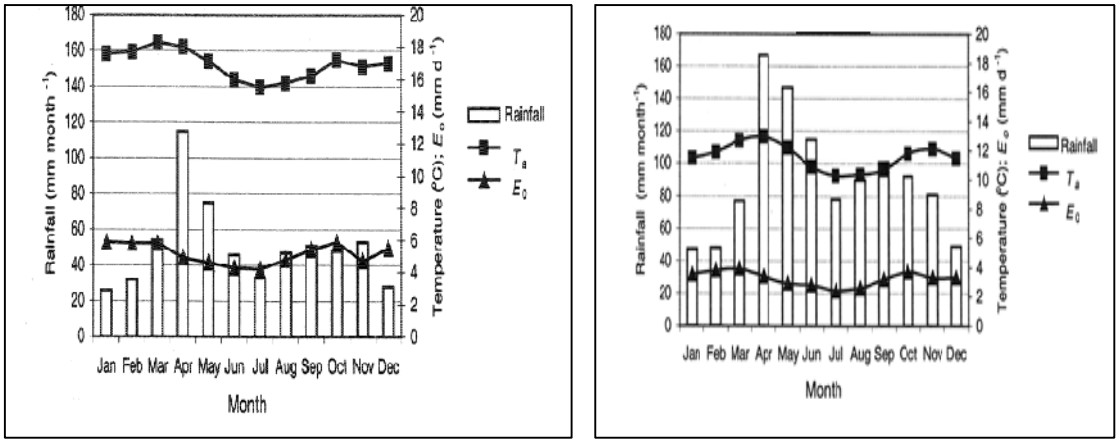


Figure 1: Map of the study area (Lake Naivasha-Malewa basin)

1.2.1 Climate

The Malewa basin belongs to a semi-arid type of climate. The rainfall distribution has a bimodal character (Figure 2). The long term spatial distribution of rain varies from 600mm at Naivasha town to 1700mm at the slopes of the Nyandarua Mountains the Kinangop plateau experiences a yearly rainfall from 1000mm and 1300mm (Becht and Higgins 2003). Longer rainy season occurs in March-May and short rainy seasons occur in October-November (Kamoni, 1988). February, July and December are the driest months of the year. The lowest temperatures are experienced in July, while the highest temperatures occur in March. The potential evaporation is about twice the annual rainfall in the semi arid area while in the upper basin humid areas, rainfall exceeds potential evaporation in most parts of the year (Farah, 2001). The annual temperature range is approximately from 8^0C to 30^0C.



(Source: Farah, 2000)

Figure 2: Monthly average rainfall, average daily temperature (1931-1983) and average daily reference E_o (1974-1983) at Naivasha town at altitude 1906 m and at North Kinangop at 2620 m

1.2.2 Vegetation

Landcover in the basin is greatly influenced by rainfall. The vegetation can be broadly classified into:

(i) Forest,
(ii) Scrub/Bush-land/native,
(iii) Bare/range brush/moorland,
(iv) Grassland/scrubland, and
(v) Agricultural land (small intensive/sparse)

The land cover of the basin is broadly categorized into four groups, namely Agriculture, Grass, Bush/scrub land and Forest. In the Nyandarua ranges, predominant land cover classes are forest and crops. The main crops are maize, potatoes and wheat. In addition there are many other vegetables grown by smallholder farmers in the middle part of the basin. In the lower catchments, there are extensive areas of grass/scrubland and bush land, which are used for livestock grazing (Muthawatta, 2004).

1.2.3 Soils

The soils in Malewa basin can be described as complex due to the influence of extensive relief variation, volcanic activity and underlying bedrocks (Sombroek *et al,* 1980). Based on studies conducted in the area (Sombroek *et al.,* 1980, Siderius, 1998; Atkilt, 2001; and Nagelhout, 2001) soils can be grouped into three (3) groups such as; 1) soils developed from lacustrine deposits; 2) volcanic; and 3) lacustrine-volcanic. These soils are highly susceptible to both erosion and compaction (Kiai and Mailu, 1998). Prominent soil degradations in the area are due to wind and water erosion, sealing and compaction (Nagelhout, 2001). The fragility of the area and various human activities seems to accelerate land degradation in the west and southern area of the basin (Hennemann, 2001). From the Kenya soil terrain (SOTWIS Ver. 1), the soils of the study area can be classified into 10 different soil categories based on the FAO classification (Figure 3).

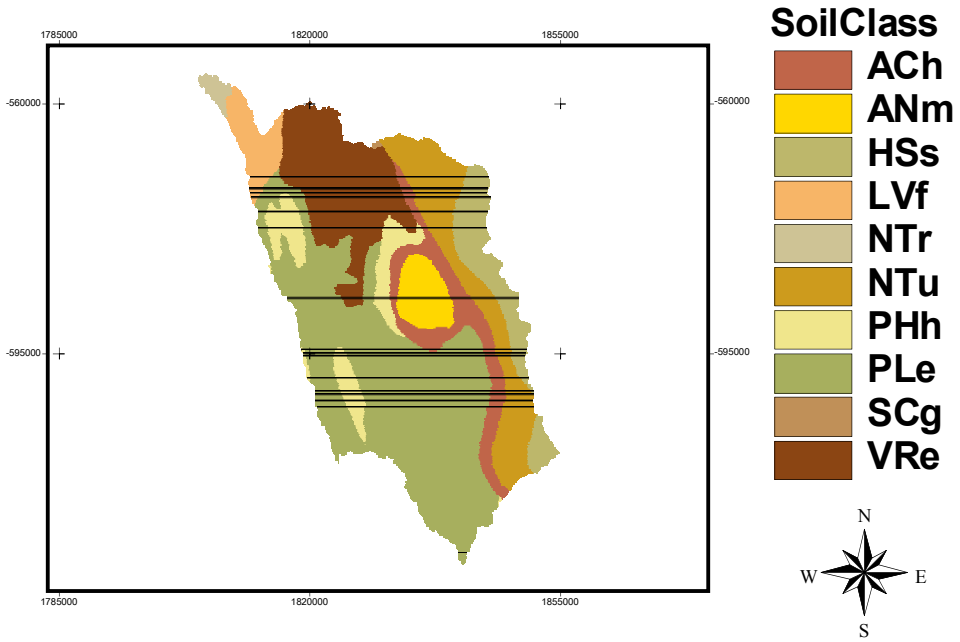


Figure 3: Soil distribution in study area

1.2.4 The Drainage Networks

The Malewa River Basin, including the Turasha river basin comprises an area of 1705 Km^2 which is approximately 50% of the larger Lake Naivasha Basin (3387 Km^2). Drainage into the Malewa starts among the steep forested eastern slopes from the Kinangop plateau (2483m a.m.s.l.) and the Aberdares (3960+m a.m.s.l.) where the average annual rainfall is 1087.5mm (Salah, 1999). Initial flow takes place in a westerly direction via a number of steeply graded tributaries that, at the lower slopes of the range, develops into four main tributaries namely, Mugutyu, Turasha, Kitiri, and Mukungi. All flow north-south before turning west and joining the River Malewa. River Turasha is the most important tributary and joins the Malewa approximately 8km east of Gilgil town (Figure 2.4). The tributaries of the Malewa river forms a very dense dendritic drainage pattern except in the Kipipiri area where they have a radial flow pattern due to the conical shape of the volcanic Kipipiri range (Graham, 1998). River Wanjohi tributary and Malewa tributary flow northward before turning west the south from Ol Kalou.

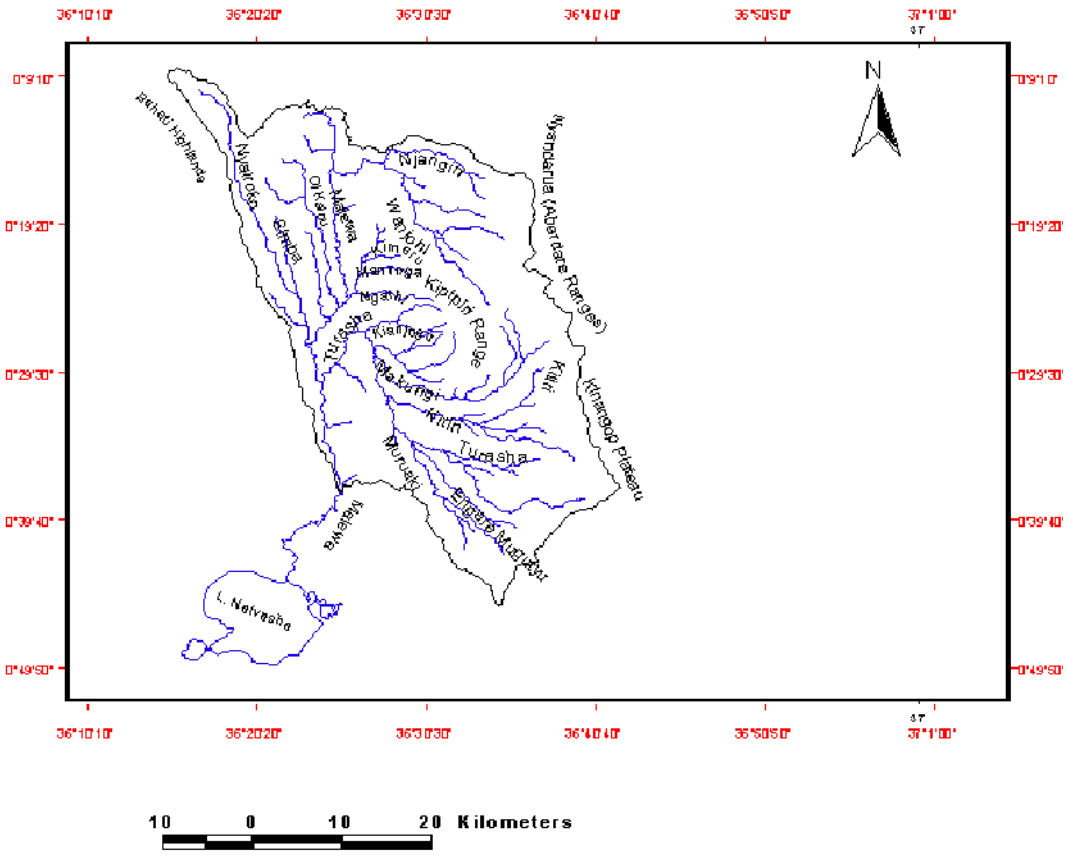


Figure 4: The Drainage Pattern of Malewa Watershed

1.2.5 Geomorphology

The study area is situated within the large African rift system and its geological evolution has influenced the geomorphology and hydrogeology in the area. Two major geomorphological groups can be observed the rift margin and rift floor plain (Graham, 1998).

The Rift Margins

These are North-South oriented and comprises of the Mau Escarpment in the west and Kinangop Plateau in the east. It is abroad flat plain ranging in height from 2379 m to a maximum elevation of about 2740 m above mean sea level. Its western margin is defined by the north-north-west trending South Kinangop fault scarp which ranges in height from 100 m to 240 m. it is steeply incised by the tributaries of Malewa River. Gorges of depths 61 and 122 m have been formed along the northern edge of the area. Along much of its length, this scarp has very steep or vertical rock face above less steep talus slopes. The crest of the scarp is between 500 and 600 m high relative to the rift floor, but is separated from the floor by a series of down faulted platforms (Figure 5).

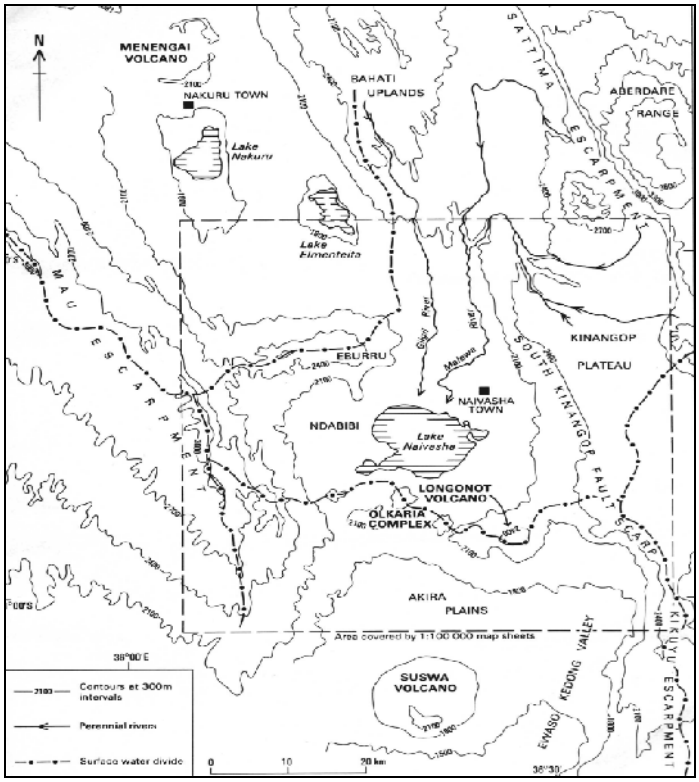


Figure 5: Detailed Physiographic Map of the Lake Naivasha Basin (Adopted after Clarke et al. 1990)

Rift floor plain

The rift floor forms part of the Gregory Rift Valley. It is diverse in its structures and topography where numerous volcanic cones and craters, scarps and lakes are found. It reaches its highest elevation (near 2000 m) in the vicinity of Elementaita and Naivasha. High points are formed by mount Longonot and Eburu, both of which rises over 2745 m above mean sea level. On the western and south-western shores of the Lake Naivasha numerous volcanic craters exist.

The Lake Naivasha dominates the Naivasha basin. The lake covers an area of approximately 145 Km^2 and stands at an elevation of 1882.4 m amsl (October 1997). The lake is smooth floored and has a mean depth of 4.7 m (Graham, 1998).

1.2.6 Hydrogeologic Setting

The hydrogeology of Lake Naivasha has been described as complex by Clarke (1990). While it is lower than the rift escarpments, it lies on the highest elevation of Rift Valley Floor. Ojiambo (1992) recognized two systems operating in the area.

(i) The Lake Naivasha subsurface seepage and the cold shallow groundwater system.

(ii) The hot highly mineralized deep geothermal systems.

Piezometric plots and isotopic studies show that underground movement of water is occurring both axially along the rift and laterally from the bordering highlands into the rift. Analysis of piezometric maps (Figure 2.6) and aquifer properties of the rocks in the area show that much of the subsurface outflow from the Naivasha catchment is to the south, via Olkaria-Longonot towards Suswa.

The effect of faulting is to cause groundwater flows from the sides of the rift towards the center to follow longer paths reaching greater depths, and to align flows within the rift along its axis. N-S rift floor faults and fractures control axial groundwater flow through the geothermal system, but this has a shallower influence than the major rift forming faults that provide deep recharge to the geothermal system.

The hydrogeology of the Naivasha Basin is simple in concept but complex in detail. At its simplest, the system can be regarded as having three main zones: the recharge, transit and discharge zones.

(i) The recharge zones are at the periphery of the Basin; in the east the highlands of the Nyandarua Mountains and Kipipiri; Eburru in the North West; and the Mau Escarpment to the west.
(ii) The transit zone covers all that area between 2,400 and 2,100 m amsl;
(iii) The discharge zone covers the basal part of the Basin, culminating in the Lake itself. This is the most complex part of the basin in hydrogeological terms.

The recharge zone is underlain by Limuru Trachyte and is thickly forested in the natural state. It provides baseflow generation in streams and rivers and deep percolation to aquifers, almost certainly fault-controlled. Faults are the dominant recharge feature in these areas.

The transit zone lies between the recharge zone (at high elevations) and the discharge zone; this encompasses the areas underlain by step-faults dropping into the basal part of the basin. Groundwater movement is dominated by faults and the weathered upper parts of individual lava flows and associated pyroclasts.

In the discharge zone (the basal part of the basin) there is generally a two-part aquifer system: a shallow aquifer from 10 to 40 m bgl, and a second deeper aquifer – sometimes separated by clay layers or basalt lava flows but in hydraulic continuity with the shallow aquifer – below about 50 m bgl. Actual depths and thickness vary across the basal area.

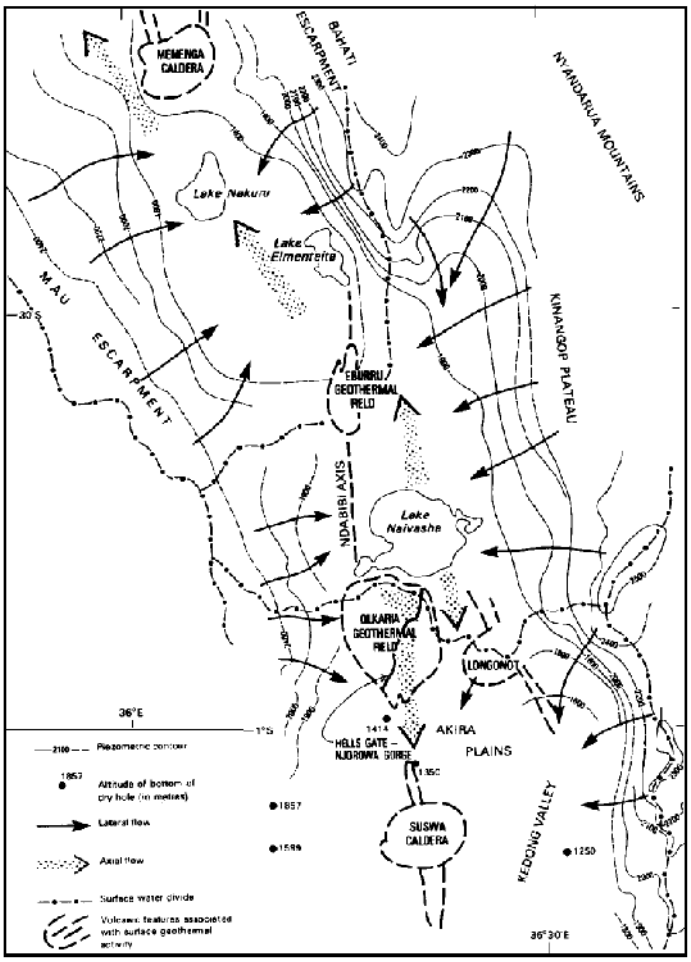


Figure 6: Piezometric Map of Lake Naivasha and Vicinities (Taken from Clarke (1990)

2.0 Methods and Analysis

2.1 Hydrologic Model

The Soil and Water Assessment Tool is a river basin model that was developed for the USDA Agricultural Research Service, by Blackland Research Center in Texas (http://www.brc.tamus.edu/blackland/

The SWAT model is a widely known tool that has been used in several cases world-wide. SWAT has the ability to predict the impact of land management practices on water, sediment yield and agricultural chemical yield in large complex watersheds (Neitsch *et al*., 2002). The present study focuses only on the hydrological component of the model. SWAT is a physical based model. The model takes into account such data as climate, soil properties, topography, land cover and management, and produces outputs with the use of common hydrological equations. Apart from the ability to take into account land use and soil data, SWAT differs from other physical models in its ability to separate the watershed into sub-basins and Hydrologic Response Units (HRUs). The main basin is divided into smaller ones, by selecting points on the stream network that act as outlets. In this way, the model can provide output data, such as discharge, at specific points of the river network. Figure 7 presents a diagram of the SWAT process.

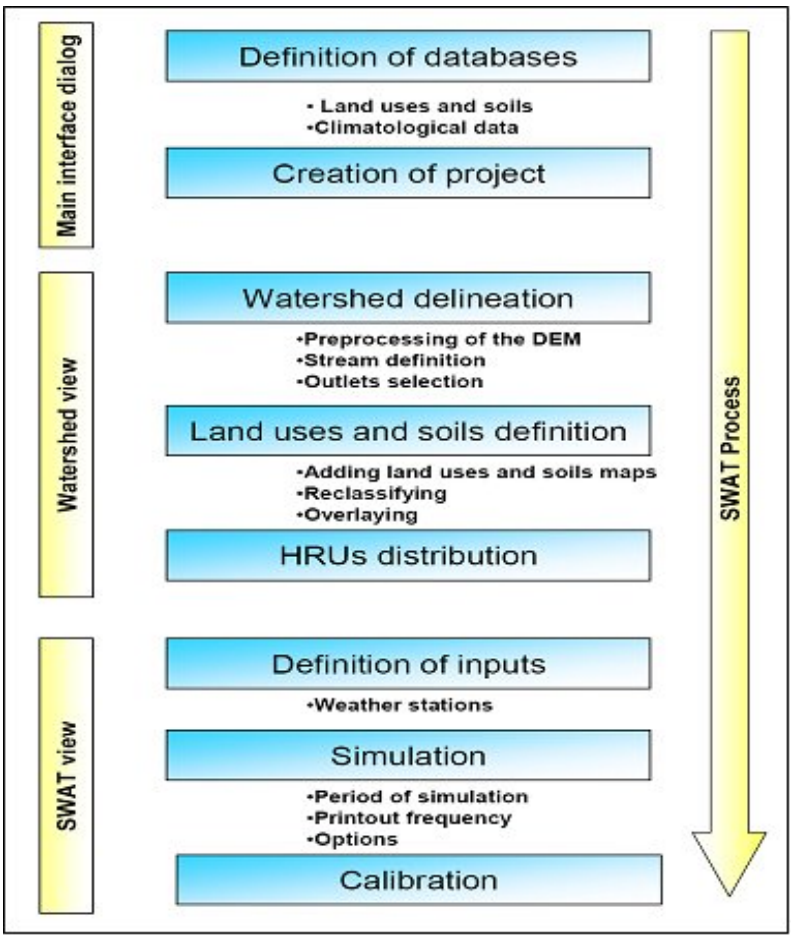


Figure 7: Representation of the SWAT model process

2.2 Input Data

Available data that were used for modeling are depicted in Table 1.

Table 1: Model input data sources for the Malewa Watershed

Data Types	Scale	Source	Data description/properties
Topo-sheets	1:50,000 and 1:250,000	Survey of Kenya	Boundary, drainage, geo-referencing
Soils (KENSOTER SOTWIS version 1)	1:1M	ISRIC	Soil physical properties e.g. bulk density, texture, saturated conductivity, etc.
Land use	1:250,000	1980 Landsat data by the Japan International Co-operation Agency, JICA, National Water Master Plan, Kenya	Land use classification valid for 1980
Weather		KMD	Daily precipitation and temperature,(9036002, 9036025, 9036054, 9036062, 9036183, 9036241, 9036281, 9036290, 9036336)
Stream flow		Ministry of water and Irrigation	Daily stream flow (2GB01, 2GB03, 2GB04, 2GB05, 2GB07, 2GC04, 2GC05, 2GC07) for a period starting from 1959-2003
BMP			Pre- and post-management information

2.3 Modeling Process

The preliminary step was the definition of the databases (dbf tables) i.e., soil and land use parameters, and climatological data. Each table had to be defined clearly using the nomenclature provided in the SWAT user's manual. The climatological data were added in different files presenting each parameter and the location of their meteorological station.

The watershed delineation process builds the streams and the sub-basins using the Digital Terrain Model. The burn-in option permits the use of an existing digitized stream network. The digitized stream network when uploaded into the SWAT model after conversion from geographic coordinates to Lambert Azimuthal Equal Areas, shifted by one pixel to the left hence was not used.

For the land use and soil definition, raster or shape files were added to the Watershed view in ArcView 3.2 and linked to the SWAT database. To use the maps provided, the SWAT interface requires a table linking the values represented to types already defined in the hydrological model. For the land use, some default categories are already provided in this version of SWAT with two themes: land cover and urban land. As an example, Table 3.2 represents the look-up table for the land use database. The land use mapped in the shapefile is linked to default categories present in SWAT.

Table 2: Relation between the land use map and the SWAT database

Land use shapefile	SWAT database
Forests, woodland	FRST Forest-Mixed
Agricultural Land	AGRL Agricultural Land Generic
Infrastructures	UINS Institutional
Heath land, Brush land,	RNGB Range Brush
Residential	URMD Residential – Medium Density
Marshland, peat bog	WETN Wetlands – Non Forested
Water	WETN Wetlands – Non Forested
Rocks	RNGB Range Brush
Sands and Pebbles	FRST Forest-Mixed

The land use 'Water' exists in the SWAT database but it is advisable to use Wetlands because this special land use could create errors in the computation of the hydrological network (Renaud, 2004).

In SWAT, a watershed is divided into multiple sub watersheds, which are then further subdivided into HRUs that consist of homogeneous land use, management, and soil characteristics. The HRUs represent percentages of the subwatershed area and are not identified spatially within a SWAT simulation. The water balance of each HRU in the watershed is represented by four storage volumes: snow, soil profile (0 to 2 meters), shallow aquifer (typically 2 to 20 meters), and deep aquifer (more than 20 meters). Flow, sediment, nutrient, and pesticide loadings from each HRU in a subwatershed are summed, and the resulting loads are routed through channels, ponds, and/or reservoirs to the watershed outlet.

HRUs within each subbasin are defined by first selecting land uses whose percentages (based on area) are greater than the user-defined land use threshold percentage and within those selected land uses, by selecting the soils whose percentages are greater than user-defined soil threshold percentage (Neitsch *et al*., 2002). SWAT model operates on a daily time step and is designed to evaluate the impacts of different management conditions (point and nonpoint sources) on water quality in large ungauged basins. Major components of the model include hydrology, weather, erosion, soil temperature, crop growth, nutrients, pesticides, and agricultural management. A complete description of all components can be found in Arnold *et al*., (1998) and Neitsch *et al.,* (2002).

Three options exist in SWAT for estimating surface runoff from HRUs – combinations of daily or sub-hourly rainfall and the Natural Resources Conservation Service Curve Number (CN) method (Mockus, 1969) or the Green and Ampt method (Green and Ampt, 1911) and for the study the CN method was chosen. This option was chosen because there were no hourly or sub-hourly rainfall for first option and no infiltration records were taken for Green-Ampt method. Three methods for estimating potential evapotranspiration are also provided: Priestly-Taylor (Priestly and Taylor, 1972), Penman-Monteith (Monteith, 1965), and Hargreaves (Hargreaves *et al.,* 1985). Sediment yield was calculated with the Modified Universal Soil Loss Equation (MUSLE) developed by Williams and Berndt, (1977). Neitsch *et al.,* (2001) provide further details on input options. Additional information and the latest model updates can be found at http://www.brc.tamus.edu/swat/.

Once the land use and soil data have been reclassified, converted to raster and overlaid, the hydrologic response units are created by the combination of soil and land use. The SWAT view was then activated and it allows the input of other data such as climatological data. Concerning rainfall, temperature, solar radiation, wind speed or relative humidity, the daily inputs can be either simulated or defined by dbase tables. In this project, the weather stations used are the daily values defined by the temperature (minimum and maximum), the rainfall and the wind speed. Because of the lack of temperature data in the study area, a relation between altitude and monthly temperature has been used in this study (see Appendix 5). The relation between altitude and temperature has been quoted from a report by the Ministry of Agriculture and Livestock Development. According to the report, the relations are based on data from 160 stations in Kenya. Data on absolute and mean, maximum and minimum, monthly and annual temperatures for the 160 stations are given in a publication of the East African Meteorological Department (EAMD 1970). Also the EAMD publication gives the equations relating the temperatures in Celsius (^{o} C) to the altitude in meters (m). Appendix 5 which was extracted from the report shows the equations for the different months and for the average, minimum, and maximum temperature. The monthly data were then extrapolated to get the mean daily values.

Humidity, solar and wind data were not available hence simulation of SWAT was used. In the case where all inputs have been successfully entered, simulation proceeded. The period of simulation, the printout frequency and some options such as the channel water routing method and the water quality processes have to be chosen to run SWAT. In this study, a yearly/monthly and daily printout on the period 1972 – 2003 was used. From the 1st Precipitation of January 1972, to the 31st Precipitation of December 2003, the outputs were then fully simulated. The outputs of SWAT are in different types: grids, shape files and tables. The results are presented in four main tables, i.e., Summary output file; HRU output file; sub-basin output file and main channel/reach output file.

2.3.1 Sensitivity Analysis

Large complex watershed models contain hundreds of parameters that represent hydrologic and water quality processes in watersheds. Model predictions are more sensitive to perturbation of some input parameters than others, even though the insensitive parameters may bear a larger uncertain range. Thereby, adjustment of all model parameters for a given study area not only is cumbersome, but is not essential. Sensitivity analysis was done through the SWAT model sensitivity analysis tool. The AVSWATX sens-Auto-Unc was loaded and sensitivity analysis selected. The dialog window allows the selection of scenario and simulation target. The output variables selected was flow with usage of observed flow data. The observed flow data used was at the basin outlet 2GB01.

Table 3 show amongst many SWAT parameters that are adjusted during sensitivity analysis process.

Table 3: SWAT Parameters

	Parameter	Description	Min	Max	Units	SWAT ıt e
1	CN2	Initial SCS runoff curve number for moisture condition II	35	98		MGT
2	SLOPE	Average slope steepness	0	0.6	M/m	HRU
3	SLSUBBSN	Average slope length	10	150	m	HRU
4	ESCO	Soil evaporation compensation factor	0	1		HRU
5	CH-N1	Manning's "n" value for tributary channels	0.00	30		SUB
6	CH-S1	Average slope of tributary channels	0	10	m/m	SUB
7	CH-K1	Effective hydraulic conductivity in tributary channel alluvium	0	150	Mm/hr	SUB
8	CH-N2	Manning "n' value for the main channel	0.00	0.3		RTE
9	CH-S2	Average slope of the main channel along the channel	0	10	m/m	RTE
10	CH-K2	Effective hydraulic conductivity in main channel alluvium	0	150	Mm/hr	RTE
11	GWQMN	Threshold depth of water in shallow aquifer for return flow to occur	0	500	Mm	GW
12	ALPHA-BF	Base flow alpha factor	0	1	Days	GW
13	GW-DELAY	Ground water delay time	0	500	Days	GW
14	GW-REVAP	Ground water "revap" time	0.02	0.2		GW
15	SOL-AWC	Available water capacity of the soil layer	0	1	Mm/mm	SOL
16	CH-EROD	Channel erodibility factor	0	0.6	Cm/hr/pa	RTE

17	CH-COV	Channel cover factor	0	1		RTE
18	SPCON	Linear coefficient for calculating maximum sediment re-entrained	0.00	0.01		BSN
19	SPEXP	Exponent	1	1.5		BSN
20	PRF	V peak rate adjustment factor for sediment routing in channel network	0	2		BSN
21	USLE-P	USLE equation support practice factor	0.1	1		MGT
22	USLE-C	Maximum value of USLE equation for cover factor for water erosion	0.00	0.5		CROP DAT
23	SOL-LABP	Initial soluble P concentration in soil layer	0	100	Mg/kg	CHM
24	SOL-ORGP	Initial soluble P concentration in soil layer	0	400	Mg/kg	CHM
25	SOL-NO3N	Initial NO3 concentration in soil layer	0	5	Mg/kg	CHM
26	SOL-ORGN	Initial organic N concentration in soil layer	0	100	Mg/kg	CHM
27	RS1	Local algae settling rate at 20^{0c}	0	2	m/day	SWQ
28	RS2	Benthic (sediment) source rate for dissolved P in the reach at 20^{0c}	0.00	0.1	Mg/m^2 day	SWQ
29	RS4	Rate coefficient for organic N settling in the reach of 20^{0c}				
30	RS5	Organic P settling rate in the reach at 20^{0c}				
31	BC4	Rate constant for mineralization of P to dissolve P in the reach at 20^{0c}				
32	A10	Ratio of chlorophyll –a to algae biomass				
33	A11	Fraction of algal biomass that is nitrogen				
34	A12	Fraction of algal biomass that is phosphorous				
35	RHOQ	Algal respiration rate at 20^{0c}				
36	K-P	Michaelis menton rate saturation constant for phosphorus				

2.3.2 Model Calibration

Calibration of a watershed model is essentially the exercise of adjusting model parameters such that model as described by Beck *et al*. (1997):

(i) Soundness of mathematical representation of processes,

(ii) sufficient correspondence between model outputs and observations, and

(iii) Fulfillment of the designated task.

Model calibration is the exercise of adjusting model parameters manually or automatically for the system of interest until model outputs adequately match the observed data. The credibility of model simulations is further evaluated by investigating whether model predictions are satisfactory on different data sets. Calibration was done through the automatic calibration tool in AVSWAT2005. Procedure provided by (Santhi *et al*., 2001b) was followed.
The calibration tool consists of three sub-tools, i.e.,AVSWATX extension; landuse-Land cover splitting tool; SSURGO data Tools; AVSWATX Sens-Auto-Unc; sensitivity analysis and auto-calibration and uncertainty.

The land-land cover splitting tool was used to split the Agriculture close into onion, potato, carrot and cabbage during scenario development for the selected target areas for implementing PES.

Simulation runs were conducted on a daily/monthly basis to compare the modeling output with the corresponding observed discharge. The calibration considered fourteen model parameters that can be summarized in three groups: (1) Parameters that govern surface water processes, including curve number (CN), soil evaporation compensation factor (ESCO), plant uptake compensation factor (EPCO), and available water capacity of the soil layer (SOL_AWC; (2) Parameters that control subsurface water processes, including capillary coefficient from groundwater (GW_REVAP), groundwater delay (GW_DELAY), and deep aquifer percolation fraction (RCHRG_DP); And (3) parameters that influence routing processes, including Manning's roughness coefficient in main channel routing (CH_N(2)) (Neitsch *et al*., 2002). One parameter was adjusted while others were kept unchanged.

2.3.3 Model validation

Data for a period of twenty-one years from January 1st, 1981 to December 31st, 1995 was used for validating the SWAT model for the Malewa River Basin.

2.3.4 Model Evaluation Criteria

The accuracy of SWAT simulation results was determined by examination of the coefficient of determination (R^2) and the Nash and Sutcliffe model efficiency coefficient (E_{NS}) (Nash and Sutcliffe, 1970). The R^2 value indicates the strength of the linear relationship between the observed and simulated values. The E_{NS} simulation coefficient indicates how well the plot of observed verse simulated values fits the 1:1 line. The E_{NS} can range from 2:1 to 1:1, with 1 being a perfect agreement between the model and real data (Santhi *et al*., 2001). E_{NS} is defined as:

$$\mathbf{E_{NS} = 1 -} \left[\{\sum_{i=1}^{n}(Measured_i - simulated_i)^2\} / \sum (measured_i - \frac{1}{n}\sum_{i=1}^{n} measured_i)^2\right] \quad \textbf{Equation 1}$$

E_{NS} values range from 1.0 (best) to negative infinity. E_{NS} is a more stringent test of performance than R^2 and is never larger than r^2. E_{NS} measures how well the simulated results predict the measured data relative to simply predicting the quantity of interest by using the average of the measured data over the period of comparison. A value of 0.0 for E_{NS} means that the model prediction are just as accurate as using the measured data average to predict the measured data. E_{NS} value less than 0.0 indicate the measured data average is

better predictor of the measured data than the model predictions while a value greater than 0.0 indicates the model is a better predictor of the measured data than the measured data average. The simulation results are considered to be good if $E_{NS} \geq 0.75$, and satisfactory if $0.36 \leq E_{NS} \leq 0.75$ (Van Liew and Garbrecht, 2003).

2.3.5 Criterion for Target sub-basin Area Selection

The following parameters were considered in selecting the principal target areas for pilot PES implementation:

- Water yield (model output)
- Sediment yield (model output)
- Nutrient load/pollution load (Phosphorous and Nitrates)
- Water conflicts (based on literature review of previous studies)
- Population density (based on 1999 census)
- Landcover/landuse activity
- Water abstraction points
- Availability of historical data (streamflow)
- Rainfall amount (input)
- Recharge and Discharge zones.

2.3.6 Scenario Analysis

The following scenarios (Table 4) were adopted on the two selected priority areas:

Table 4: Scenario Analysis

N	Scenario	Description
1	Base Scenario (Business as usual)	This is the status quo condition i.e. Business as usual
2	Horticultural scenario	This scenario consisted of various horticultural crops in equal proportions making 100% i.e. 25% cabbage,25% carrot 25% onion and25% potatoes i.e. an horticultural scenario (see sample output in Appendix3)
3	100% High Density Residential	This consisted 100% residential which are highly dense
4	53% Forest and 47% range brush	The scenario consisted with only two types of vegetation i.e. Forest at 53% and Range brush at 47%
5	100% Forest	This scenario was 100% Forest. The whole area was put under forest wholly

6	Best Management practice	This scenario involved implementing two BMP. a) Filter strip (0, 1, 5, 10 m edge). This scenario involved altering the filter width from no filter width 0m to 1, and running the scenario, then 1m, 5m, and 10m respectively. Each scenario was compared with base scenario 0m b. Contours (P=0.1, P=0.65, and P=1). This scenario involved implementing contouring practices. In order to achieve this, the P in the support practice factor in USLE equation was modified from base condition 1 with no erosion control to erosion controlled structure with USLE-P value of 0.1, and 0.65 respectively.

3.0 Results and Discussions

3.1 Sensitivity Analysis

The main objective of sensitivity analysis was to explore the most sensitive parameters to facilitate model calibration procedure. The SWAT model outputs depend on many input parameters related to the soil, land use, management, weather, channels, aquifer, and reservoirs. Table 5 summarizes the 27 SWAT parameters selected out of for sensitivity analysis in this study. These parameters were chosen based on the results of auto-sensitivity analysis run.

Table 5: Parameters used in sensitivity analysis

	Objective Function			Objective Function	
Parameters	OF	OUT	Parameters	OF	OUT
SMFMX	1	1	SOL_AWC	6	5
SMFMN	28	28	Surlag	5	10
ALPHA_BF	28	28	SFTMP	28	28
GWQMN	1	2	SMTMP	28	28
GW_REVAP	28	11	TIMP	28	28
REVAPMN	28	28	GW_DELAY	28	16
ESCO	28	28	rchrg_dp	28	13
SLOPE	9	8	Canmx	8	9
SLSUBBSN	4	3	sol_k	7	4
TLAPS	10	14	sol_z	12	7
CH_K2	28	28	sol_alb	28	28
CN2	2	6	Epco	28	15
CN2	3	1	ch_n	11	12

The OF refers to "objective function' thus the error function compared to observations. If you have observations, this line will give the most valuable information selecting the parameters for a calibration in which case, the first line labeled **OF** (Objective Function) was used to select the parameters for auto calibration. **OUT** refers to the model output (default, the average output). The second line is the output using the observed data set. Figure 8

illustrates the parameters plotted with the least value showing the most sensitivity parameter.

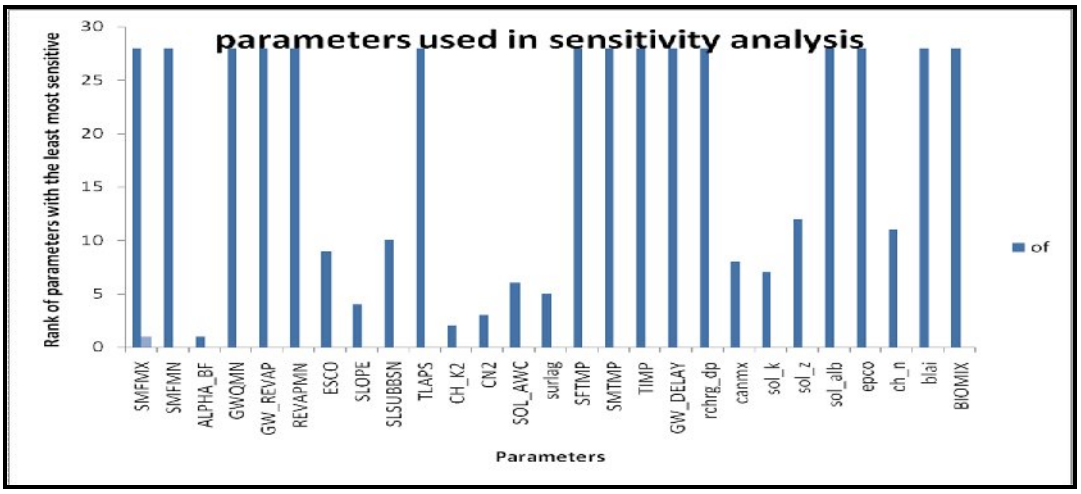


Figure 8: A plot of the SWAT parameters used in sensitivity analysis.

From the sensitivity analysis (Figure 5.8), the following parameters shown in Table 6 were selected for calibration.

Table 6: Initial and finally adjusted parameter values of flow calibration

No	Parameter	*Description*	*Effect on simulation when parameter values increase*	*Range*	Initial Value	Adjusted Value
1	CN2	Initial SCS CN II value	Increase surface runoff	35-98	Default	37.438
2	GWQMN	Threshold water depth in shallow aquifer for flow (mm H_2O)	Decrease baseflow	0-5000	1000	2279.3
3	ESCO	Soil evaporation compensation n factor	Decrease evaporation	0-1	1	0.55
4	SLOPE	Average slope steepness (m/m)	Increase the lateral flow	0-0.6	Default	0.493
5	RCHRG_DP	Deep aquifer percolation fraction	Increase deep aquifer recharge	0-1	0.05	0.107
6	GW_REVAP	Groundwater “revap” coefficient	Decrease baseflow by increasing water transfer from shallow aquifers to root zone	0.02-0.2	0.02	0.042
7	GW_DELAY	Groundwater delay (days)	Increase the time between water exits the soil profile and enters the shallow	0-500	31	36.979

			aquifer			
8	SLSUBBSN	Average slope length (m)			60.967	108.4
9	SOL_K	Saturated hydraulic conductivity (mm/hr)		-50%-50%		2.392
10	REVAPMIN	Minimum shallow aquifer depth for return flow to occur (mm H_2O)	Increased so that groundwater return flow occurs before 'revap' (transfer of groundwater to upper soil layers)		0.5	316.6
11	SURLAG	Surface runoff lag time (hours)	Reduced so that some portion of surface runoff is lagged one day before reaching the channel			1.446
12	ALPHA_BF	Baseflow alpha factor (days)	Increased to simulate steeper hydrograph recession	0.001-1	1	0.837
13	EPCO	Plant uptake compensation factor		0-1		0.444
14	SOL_AWC	Soil available water capacity (mmH2O/mm soil)	Increased base value by 70% for layer 1 inputs & 30% for all other layers for soil to hold more water	0-1	0.15	0.645

Stream flow calibration was performed for the period from 1981 through 1983 and validation period was from 1972 to1987. Calibration was performed for annual and monthly-simulated flows using observed flows from the Ministry of Water and Irrigation (MWI) gauging stations shown in Figure 5.6 and Appendix 8.

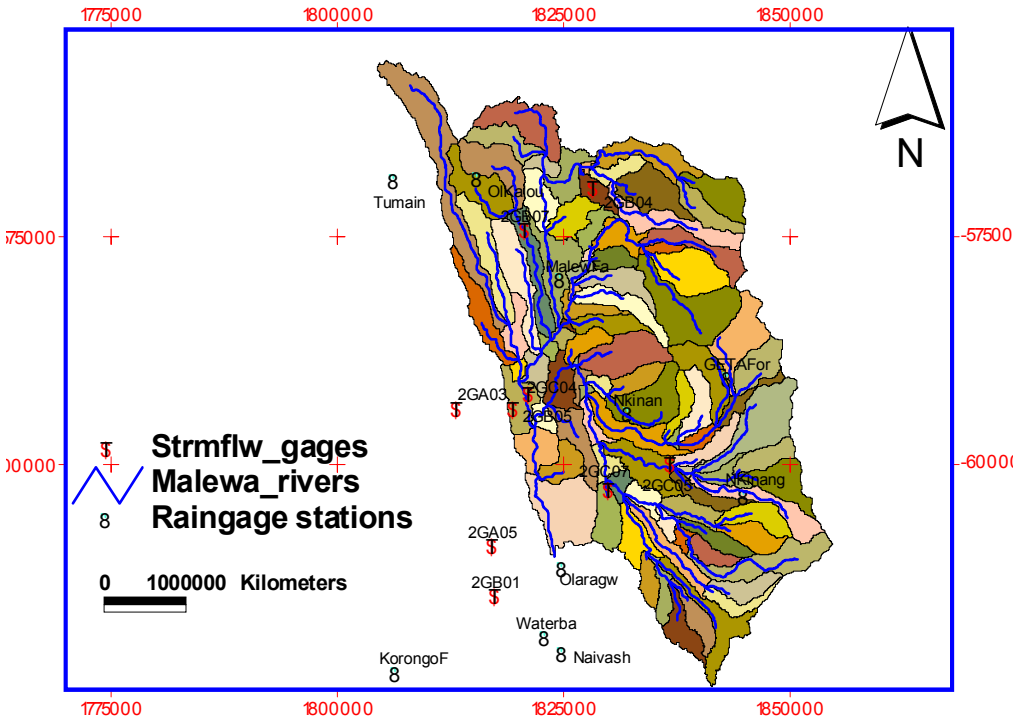


Figure 9: Subbasins and gauging stations of Malewa Watershed

Figure 9: Results of calibration at Kitiri gauging station 2GC05 at sub-basin 72 outlet.

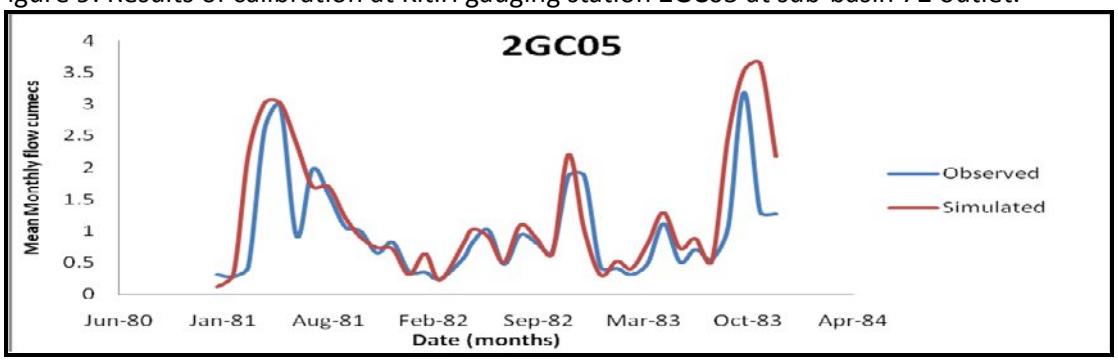


Figure 10: Stream flow calibration results at 2GC05

The next upstream gauging station calibrated was 2GB07. Figure 11 shows the calibration results at Upper Malewa station near Ndemi Bridge (station GB07 near the outlet of sub-basin 15).

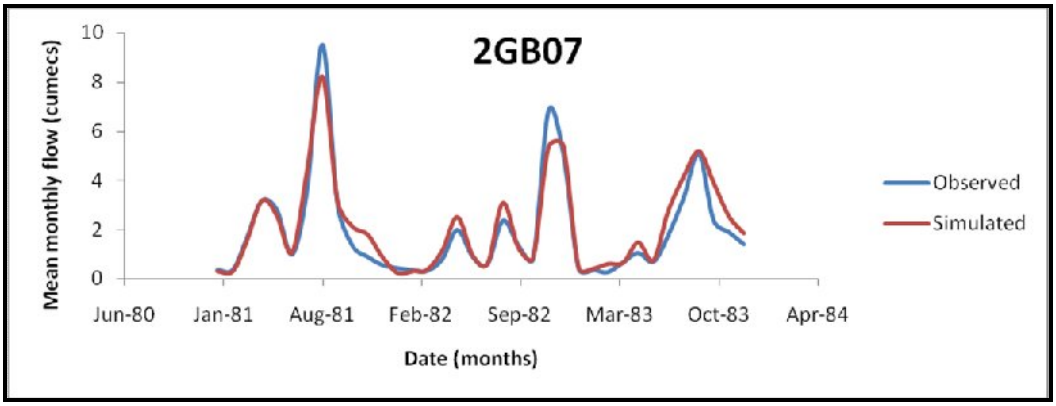


Figure 11: Calibrated streamflow for gage 2GB07

The other gauging station calibrated was the main Malewa watershed outlet gauging station at Naivasha (Station 2GB01 near the outlet of subbasin 101 main outlet for the entire basin). The calibration results are presented in Figure 12.

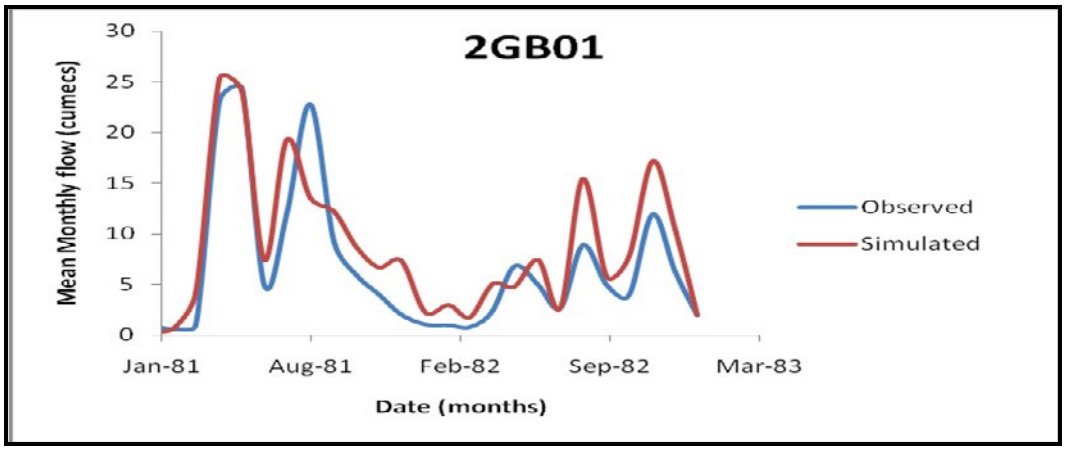


Figure 12: Calibrated streamflow for gage 2GB01

The calibration process consisted of ensuring (a) the simulated flow match the observed flow at Upper Malewa (GB07), Kitiri (GC05) and Naivasha (GB01) and (b) proper split (proportioning) of the simulated flow between surface runoff and base flow.

Surface runoff and base flow were calibrated simultaneously. Calibration parameters adjusted for surface runoff were mainly curve number (CN) and Manning's n. The parameters adjusted for base flow proportioning were groundwater revap coefficient, plant uptake compensation factor, and soil evaporation compensation factor and threshold depth of water in shallow aquifer. These parameters were adjusted within the reported ranges. The calibration for surface runoff was continued until average observed and simulated surface runoff was within 15% and R^2, and E_{NS} above 0.5, as possible. The calibration for base flow was continued until the simulated base flow was within 15% of the observed base value. Surface runoff was continually verified as the base flow calibration variables also affect surface runoff. Detailed calibration procedures for SWAT model and the definitions of

various calibration parameters are described by Neitsch *et al.,* (2002) and Santhi *et al*., (2001a) and reproduced in Appendix 2.

As can be seen from Figure 12, the calibration result for the main watershed outlet 2GB01 with R^2 of 0.80 and E_{NS} of`0.72 were not good compared to the other two gauging stations used. Beyond January 1983, there was a lot of divergence between simulated and observed hence R^2 and E_{NS} calculation was done between January 1981 and December 1982 in the case of 2GB01. This was attributed to the unreliable flow data. The unreliability of the data was attributed to inaccuracies in measured flow rates, complex relationships between water levels and flow rates in the Malewa streams, transformation of stream cross sections, and change in water surface profiles due to continuous sedimentation and stream bed scouring, etc. Another reason was due to temperature data used. Due to lack of temperature data in the study area, a relation between altitude and monthly temperature was used in this study. The equations (refer to Appendix 5) used were derived from long term data by meteorological department and gives mean monthly temperature for different altitudes in Kenya. Deriving mean daily temperatures from these equations results in over-simplicity and only one year data could be calculated and then replicated for the entire period of model run. By extrapolating the mean monthly data to daily data, unavoidable errors were bound to be introduced in subsequent calculations. Becht and Harper, (2002) stated that the Malewa basin flow data is considered unreliable after the mid 1970's. The possible causes of unreliable streamflow data are as follows; disagreement of observed water levels between gauges and streams, inaccurate results of measured flow rates, complex relationships between water levels and flow rates in streams, transformation of stream cross sections, change in water surface profiles due to continuous sedimentation and stream bed scouring, missing values, wrong value entries, error due to the accuracy of the instruments being used, error due to timing (approximation uncertainty), and hysteresis in the stage-discharge relationship.

Several statistics including the mean, coefficient of determination (R^2), and Nash-Sutcliffe prediction efficiency (E_{NS}) were used to evaluate the model predictions against the observed values (Table 7).

Table 7: Calibration Table

Gage ID	R^2	E_{NS}	Days of measured data	Mean measured data (m^3)	Mean simulated flow (m^3)	Difference between measured and simulated (m^3)
2GC05	0.77	0.76	1/1/1981-31/12/1983	2.125	1.922	0.203
2GB07	0.79	0.77	1/1/1981-31/12/1983	0.998	0.963	0.035
2GB01	0.80	0.72	1/1/1981-31/12/1982	6.723	8.062	-1.339

The R^2 value is an indicator of strength of relationship between the observed and simulated values. The Nash-Suttcliffe simulation efficiency (Nash and Suttcliffe, 1970) indicates how

well the plot of observed versus simulated value fits the 1:1 line. The prediction efficiency indicates the ability of the model to describe the probability distribution of the observed results. If the R^2 and E_{NS} values are less than or very close to 0.0, the model prediction is considered 'unacceptable or poor'. If the values are 1.0, then the model prediction is 'perfect'. Previous studies indicate that E_{NS} values ranging from 0 – 0.33 are considered to indicate poor model performance, 0.33 – 0.75 are acceptable values, and 0.75 – 1.0 are considered good (Motovilov *et al*., 1999; Inamdar, 2004). The threshold value of acceptance was taken as 0.5 for R^2 and $E_{NS.}$ A value greater than 0.5 for these variables was considered acceptable, which was the criteria used by Santhi *et al*., (2001b). In overall assessment, the model calibration was within acceptable ranges hence the model can be said to predict the flow well and can be used for prediction of flow.

As a check of the calibration results, a water balance was performed for the study area. SWAT model is based on the water balance equation

$$SW_t = SW + \sum_{i=1}^{t}[R_t - Q_t - ET_t - P_t - QR_t] \quad \text{.....(3)}$$

Where SW is the soil water content minus the 15-bar water content, t is the time in days, and R, Q, ET, P, and QR are the daily amounts of precipitation, runoff, evapotranspiration, percolation, and return flow, respectively; all the units are in mm.
Over the calibration period, the simulated basin wide water balance components on annual average basis were as follows:

- 965 mm of precipitation (R)
- 136 mm of evapotranspiration (ET)
- 668 mm of water yield (i.e. streamflow leaving the basin) partly made of
    - 15 mm of surface runoff (2.5% of water yield) (Q)
    - 368 mm of lateral flow (61.1% of water yield) (QR)
    - 219 mm of groundwater flow (36.4% of water yield) (P)

Not included in the above-simulated balance are the very minimal losses of water to deep aquifers, percolation and channel transmissions, which total less than 1% of the annual precipitation. Transmission losses are losses of surface flow via leaching through the streambed. Water losses from the channel are a function of channel width and length and flow duration and deep, confined aquifer losses which contributes return flow to streams outside the watershed.

3.2 Validation of the SWAT Model in Streamflow Prediction

Application of simulation modeling in research and decision-making requires establishing credibility, for model simulations (Rykiel, 1996). The model was validated for the period 1972-1987. This involved running the calibrated model without changing any parameter and then comparing the simulated and observed streamflow. Table 8 shows the model performance over this period.

Table 8: Validation Table results

Gage ID	R^2	E_{NS}	Days of measured data	Mean measured data (m^3)	Mean simulated flow (m^3)	Difference between measured and simulated
2GC07	0.61	0.55	1/1/1981-31/12/1991	0.236	0.922	-0.686
2GB07	0.69	0.61	1/1/1981-31/12/1991	1.288	2.456	-1.168
2GB01	0.63	0.56	1/1/1981-31/12/1991	4.975	6.893	-1.918

The validation statistics in Table 5.11 shows that the simulated flow has a good correlation with the gauged flow. The E_{NS} was found to range from 0.55 to 0.61, which is relatively small but still acceptable as this value is more than 0.5 and R^2 ranged between 0.61 and 0.69 which is above 05 and was considered as acceptable. However, the overall flow trend is well simulated by the model. These results showed that the model is able to describe the hydrologic processes of the watershed.

3.3 Selection of Priority area for Implementation of PES

3.3.1 Criterion for Priority Area Selection

The priority area for implementing pilot PES was selected based on the following parameters (Table 9):

Table 9: Criterion used for selecting target areas for pilot PES implementation

#	Parameters	Condition that must be met for the area to be selected pilot PES area
1.	Rainfall amount	Select areas with highest Rainfall and must be within the upper catchment
2.	Water yield	Select areas with highest water yields and must be within the upper catchment
3.	Groundwater Recharge and discharge zones	Select areas with highest groundwater recharges and low discharge and must be within the upper catchment
4.	Water conflicts	Select areas facing water conflicts between downstream users and upstream land owners, also areas having human-animal conflict and must be within the upper catchment
5.	Population pressures i.e. population density, poverty gap and poverty rate	Select areas with highest population density (>100 inhabitants per km^2), poverty rate and poverty gap and must be within the upper catchment

6.	Land-cover/land-use activity (anthropogenic activities)	Select areas with highest anthropogenic activities and areas facing high pressure from human activities and are considered as fragile ecosystem. These includes steep slopes >10%, undisturbed lands such as virgin forest, protected areas, range brush, and highly erodible soils and must be within the upper catchment
7.	Hydrogeology of the Malewa basin.	Select areas where the drainage pattern is concentrated and are the source of the streams within the upper catchment. Also considered here are the recharge, transit and discharge zones. Piezometric heads were also considered

Initially, the focal area selection was based on the areal rainfall distribution. Since rainfall is the prime driving force in hydrologic processes, it was ranked first. The areas with the highest annual rainfall (over 1000 mm/year) were selected (Figure 13). Another consideration was based on the drainage network formation within the study area. The drainage network defines the sub-watershed boundaries and points for monitoring and evaluating the discharge and other water quality parameters.

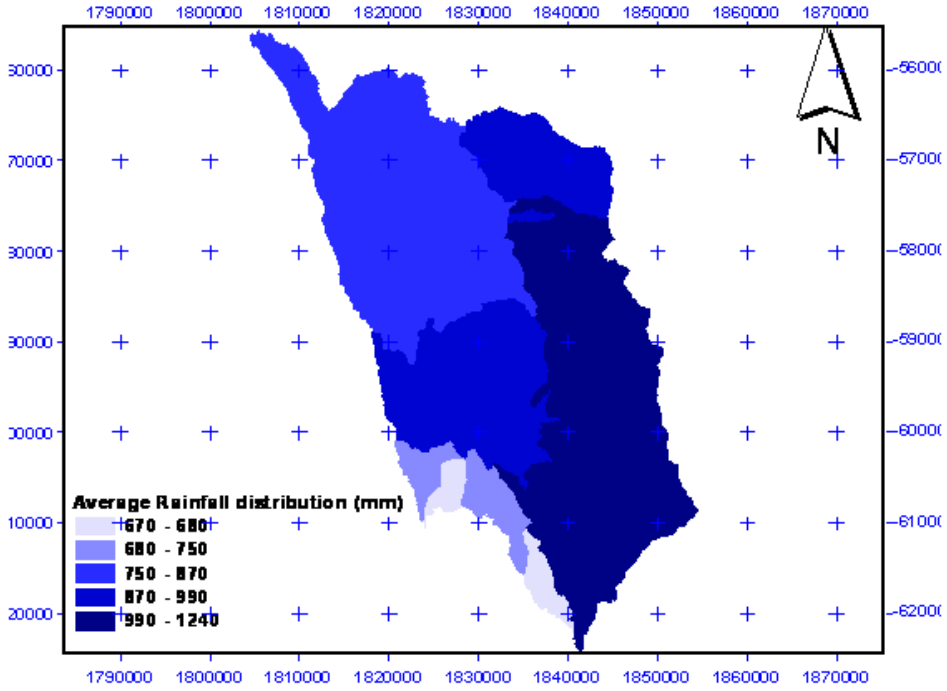


Figure 13: Yearly Rainfall distribution (1972-2003) for Malewa Watershed

The second parameter considered was water yield, recharge and discharge zones. Since the amount of water yield in a given area is a function of the rainfall amount, topographical aspects, soil and geological properties, groundwater withdrawal and watershed storage, it

was considered an important parameter in priority area selection. Areas having water yield greater than 1000mm of water yield per annum were selected (Figure 14).

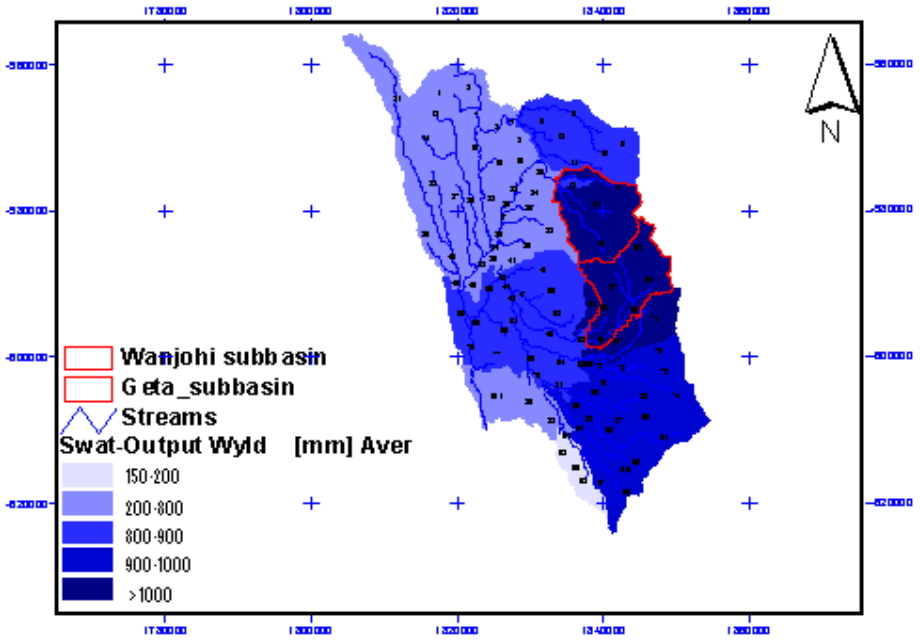


Figure 14: Mean Annual Water yield distribution for Malewa Watershed

The third parameter considered in selection of priority conservation areas was population factors such as poverty rate, poverty gap (the difference between the rich and the poor), and poverty density (Figures 15, 16 and 17). Geta, Wanjohi and North Kinangop sub catchments were selected in this category. These are the areas vulnerable to high poverty, lie within the upper catchment, and are dissected by the major Turasha tributaries (Kitiri, Nandarashi and Mukungi rivers). Human population plays a vital role in any water catchment. Accelerated erosion and excessive runoff are connected with development activities and human disturbances, e.g. clearance of fragile zones, denudation and compaction of soil through overgrazing, exhaustion of soil through intensive cropping. Erosion increases as a function of population density (Figure 15) in a given agrarian system. If the population passes a certain threshold, land starts to run short, and soil restoration mechanisms begins to fail (Pieri, 1989). One speaks of a densely populated degraded area when the population reaches 100 inhabitants per km^2 (FAO, 1996).

As populations and pressures on land grow, the poorest of the poor (Figure 16 and 17) are forced into more and more borderlands lands. Figure 15 shows poverty gap (Percentage gap to bridge for the poor to reach the poverty line) within the Malewa catchment.

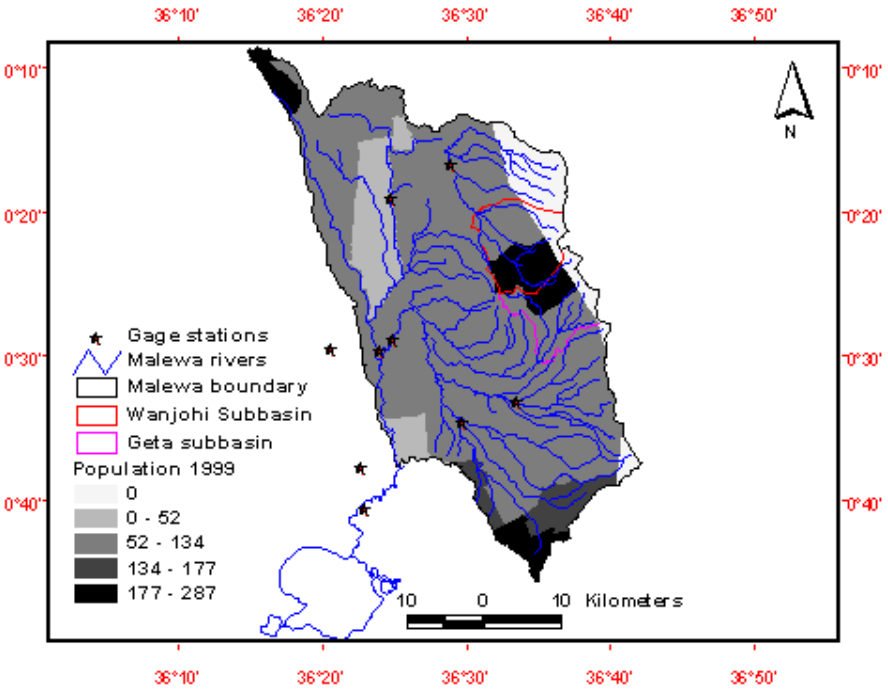


Figure 15: Population density per location (adapted from www ilri.org, 1999)

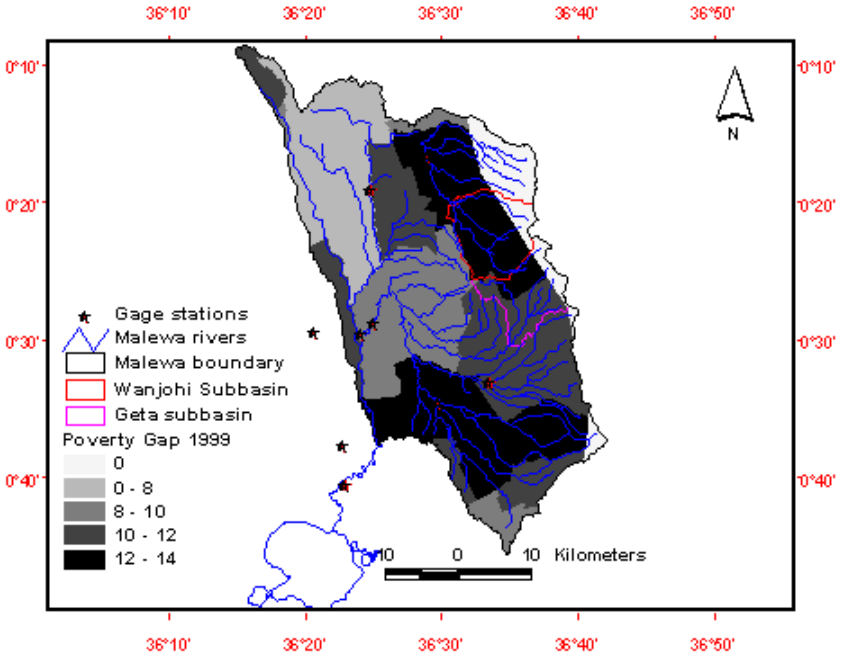


Figure 16: Poverty gap per location (adapted from www ilri.org, 1999)

In river basin headwaters, the poorest (Figure 17) settle on the most vulnerable uplands, often with high incidences of poverty rate, high slopes and thin soils. Forests are cut down, and slopes are cultivated. Soils are eroded, resulting in minimal crop yields and unsustainable livelihoods. More dangerously (insidiously) groundwater recharge is reduced, river flows become flashier and downstream flood and drought impacts can be greatly enhanced.

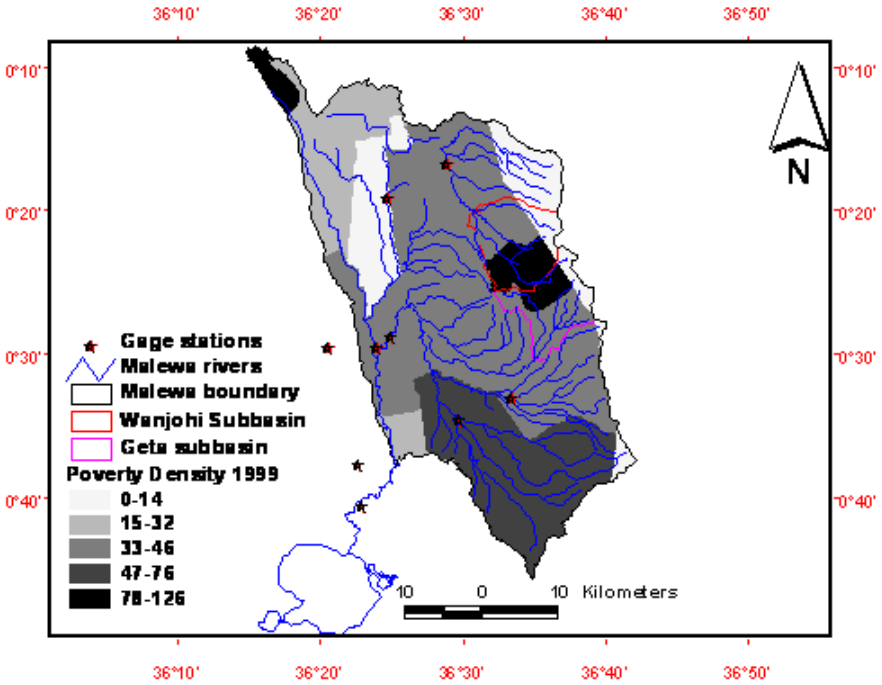


Figure 17: Poverty density per location. (adapted from www.ilri.org 1999)

Poverty also creates disincentives to manage long-term resource values, as they create the need for immediate economic returns from forestland. Population pressure such as population density, poverty rate and consequently poverty gap within the catchment has resulted in extended periods of land over-use with the consequent shortening of fallow periods, deforestation, and cultivation and grazing on marginal lands such as steep slopes greater than 15%. This lowers productivity and the vicious poverty cycle is repeated. Dispute over land and the myriad challenges relating to land use, environmental sustainability and fragmentation of plots, tend to become more frequent and more challenging when population density increases.

The next process involved previous studies mainly focusing on water conflicts (see Appendix 6), pressure on water, and pressure on vegetation. The map of pressure on vegetation (Figure 18) and the one *of* pressure on water bodies (Figure 19) indicate that the two pressures are almost complementary.

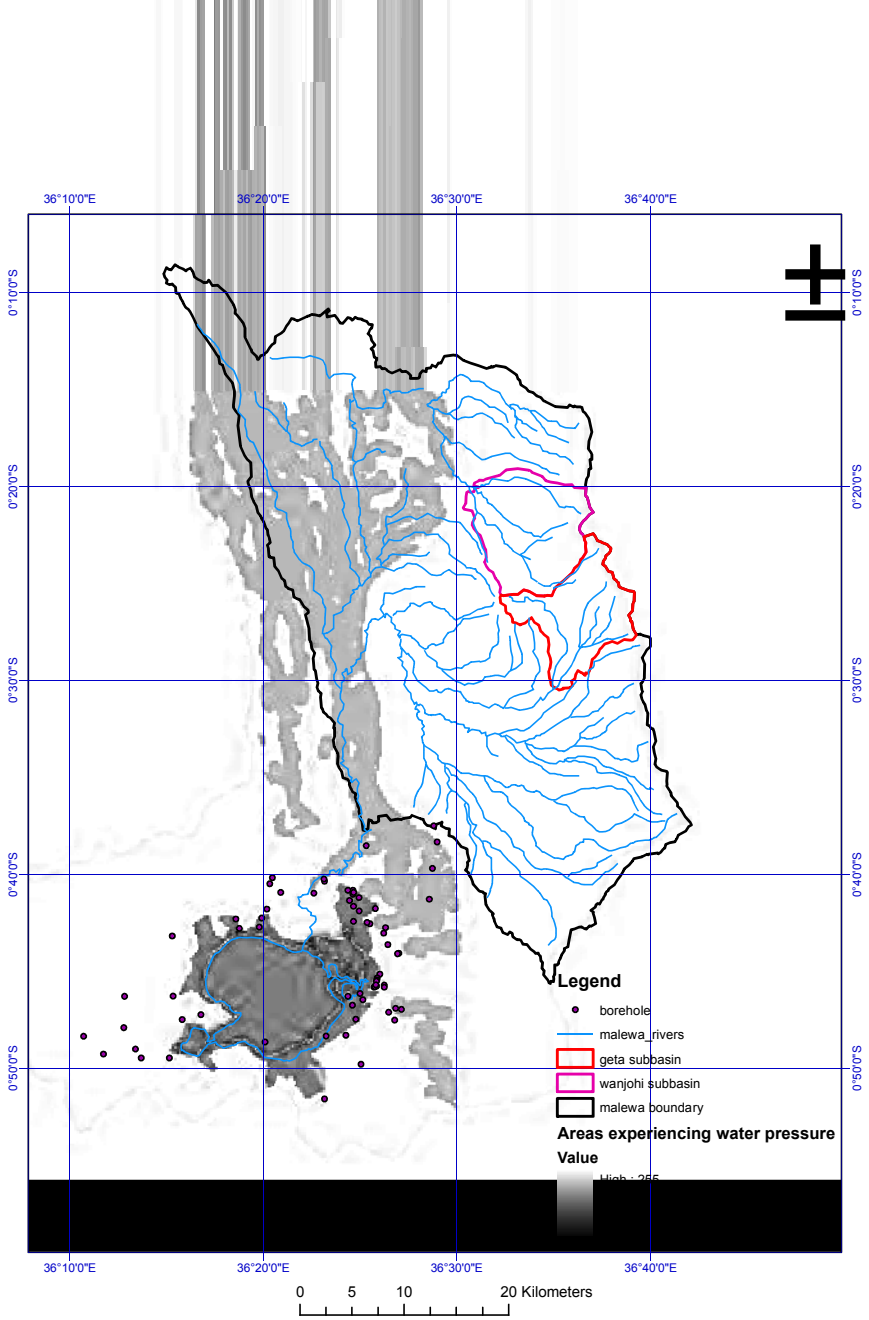


Figure 18: Pressure on Water bodies. (Adapted from Fayos, 2002)

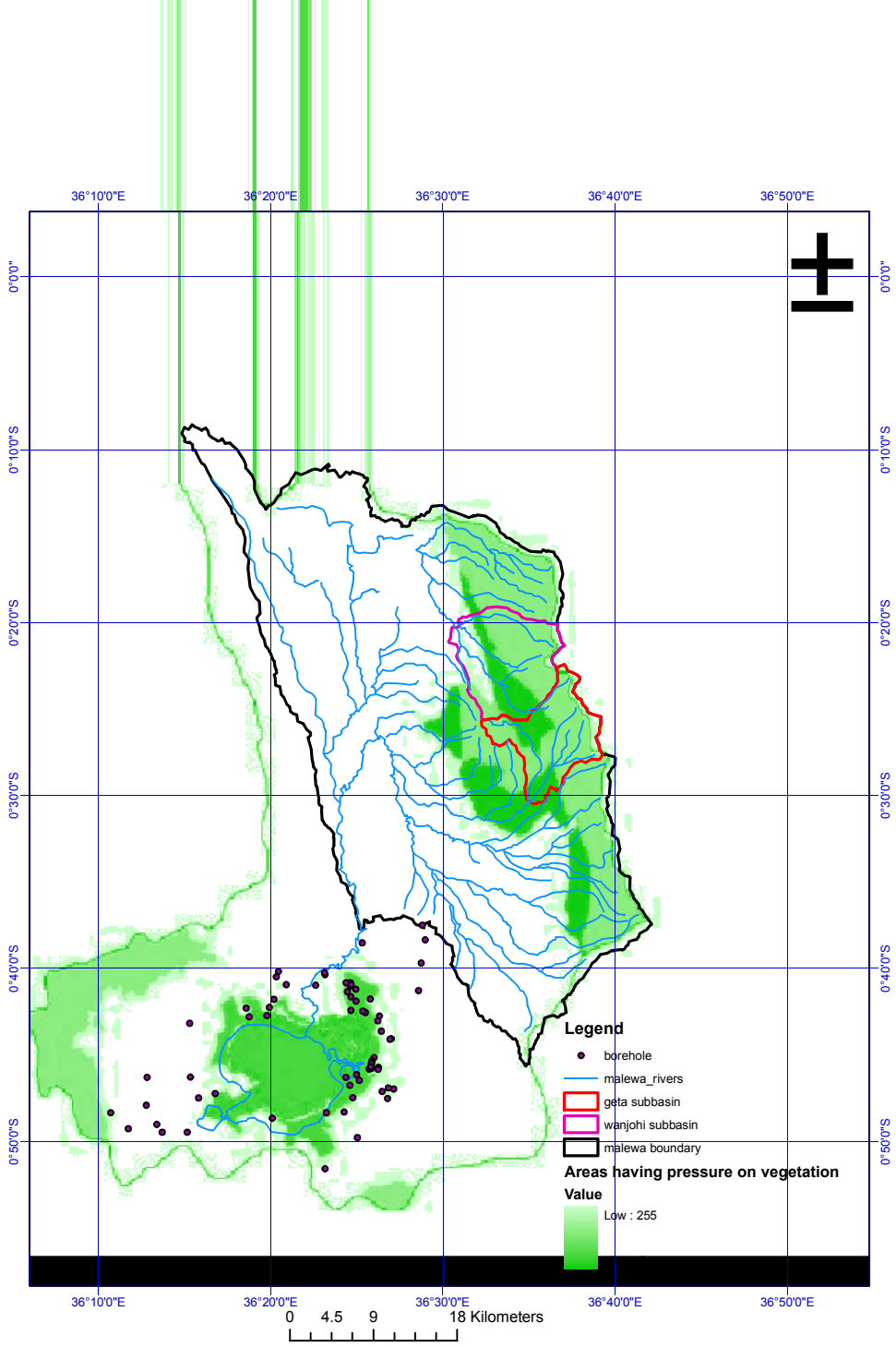


Figure 19: Pressure on Vegetation. (Adapted from Fayos, 2002)

This means that high-medium pressure on water bodies correspond with low-medium pressure on vegetation and vice versa, of course with some exceptions. However this general pattern is logical in the case of the Naivasha catchment because closeness to forest and to watercourses does not always coincide. Where the pressure is on the water body, these places have low rainfall which is usually less than evaporation. Such areas tend to be either arid or semi-arid with low population density. However, forests usually occupy the cooler zones of the catchment where rainfall exceeds evaporation, hence no pressure on water bodies.

High population densities are found in upper Malewa catchment (near the forest) and coincidently there is high fragmentation of land while places with low population density

experiences pressure on the water resources. The drier zones of the catchment are also occupied by large farms practicing irrigation compounding further the problem of water utilization. Furthermore, Figure 5.20 shows that the high and medium pressure areas appear distributed mainly in two areas:

- Around the Malewa river and
- Around Lake Naivasha

The two areas overlap very well with the densest areas of drainage where at the same time agriculture practices that are not completely rainfed are practiced. The rainfall distribution (Figure 10) also shows an area of less rainfall along the middle catchment of Malewa where irrigation needs are likely to be high. The middle catchment is also where there is the conflict of *Small Malewa farmers versus the big farms downstream (Fayos, 2002)* (Table 10) *i.e.* downstream farmers complain about water abstraction from the middle catchment.

Table 10: Water conflicts within upper and middle Malewa catchment.(Source: adapted from Fayos, 2002)

Conflict number	Conflicts	Components of the conflicts	Spatial indictor of the component and source
1	North Kinangop farmers vs. farmers middle catchment	Upper catchment destruction (Kinangop)	Forest disappeared after 1961 (forest cover according to Carey Jones, 1965 and Fayos Boix, 2002)
		Bad infrastructure	Roads in bad condition
2	South Kinangop farmers vs. small Malewa farmers	Upper catchment destruction (Kinangop)	Forest disappeared after 1961 (forest cover according to Carey Jones, 1965 and Fayos Boix, 2002)
3	North/South Kinangop farmers vs. big farmers downstream	Upper catchment destruction (Kinangop)	Forest disappeared after 1961 (forest cover according to Carey Jones, 1965 and Fayos Boix, 2002)
		Water Pollution of the rivers	Malewa and Gilgil rivers and main subsidiaries (Drainage map of the ITC Naivasha data base and sampling for river pollution from Munoz Villers,2002)
		Bad infrastructure	Roads in bad condition
4	Small Malewa farmers versus big farmers downstream	Water extraction from the rivers	Malewa and Gilgil rivers and main subsidiaries (Drainage map of the ITC Naivasha data base Fayos, B.C.,2002)
		Water Pollution of the rivers	Sampling points for river pollution Munoz Villers (2002)
5	Mixed cattle/agriculture versus large commercial farms	Land utilization	Water consumption by farmers (Pereira, 2002)

6	Farmers versus Fishermen	Water pollution of the lake	Point pollution sources from Munoz Villers (2002) and area of non point source pollution (information from Mulot Villers Fayos, B.C., 2002)
		Water Extraction from the lake	Water consumption by farmers (Pereira, 2002)
12	Water supply GETA project	Water supply GETA project	GETA settlement (own elaboration)
13	Nakuru water project	Nakuru water project	Nakuru settlement (own elaboration)
16	Water supply Naivasha	Water supply Naivasha	Naivasha town (Mena, 2002)
	GETA project	GETA project	GETA settlement (own elaboration)

Higher pressure on vegetation is distributed mainly in the areas surrounding the Aberdares (Geta and North and South Kinangop), and Kipipiri forests (Figure 17). Population growth is also causing tremendous pressure on natural vegetation such as forest and rangelands. The areas marked as high pressure are where the forest has disappeared in the last 40 years. These areas were established as high density settlements and coupled with the bad access roads; the areas have seen reduction in the competitiveness in marketing agricultural products hence forcing the inhabitants to use the forest as an alternative economic source which is seen as the most economical venture. With people living closer to the forested areas, a pressure is created on production resources with the following practice such as timber logging, forest grazing, *shamba* systems and forest encroachment, leading to change in opportunities created by markets, an outside policy intervention, loss of adaptive capacity, and changes in social organization and attitudes. Consequently, the anthropogenic activities lead to further siltation as a result of increased sediment yield. Activities including tillage, manure application, cutting down of forests and intensive livestock grazing affect water quality and quantity within the Turasha and Kitiri catchment tributaries of the Malewa River Basin. Figure 20 shows the conflicts of interest in Table 10.

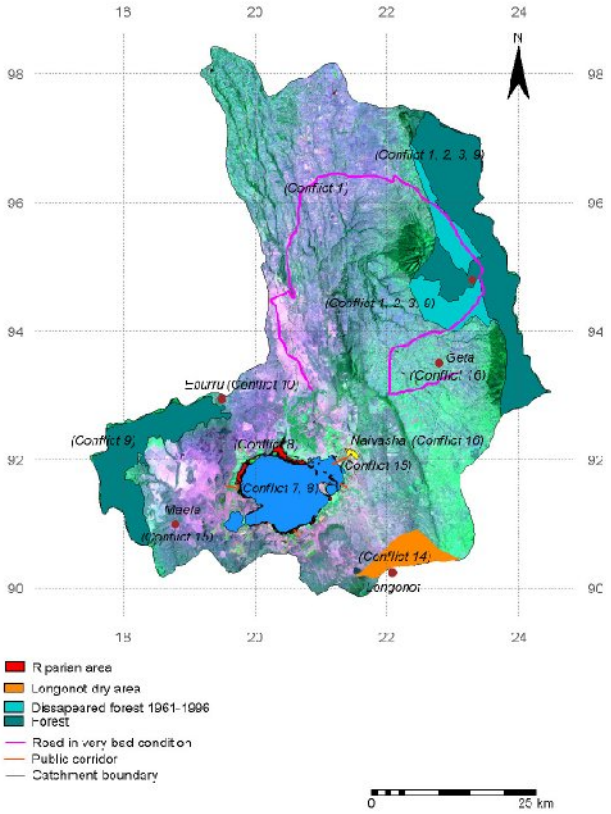


Figure 20: Areas of conflicts indirectly related to water

(In the back a False Color Composite TN 96 Bands 3, 4, 5, green areas correspond to vegetation). **Source**: Fayos, 2002)

The other parameter considered in selection of priority area was the hydrogeology. The hydrogeology of the Naivasha Basin is simple in concept but complex in detail. The complexity is due to the rift valley geometry and tectonic activities (Clarke *et al*, 1990). At its simplest, the hydrogeology system can be regarded as having three main zones: the recharge, transit and discharge zones. Figure 21 shows the general recharge zones within the catchment. The recharge zones are those at the periphery of the basin; in the east the highlands of the Nyandarua Mountains and Kipipiri ranges. The transit zone covers all that area between ≈ 2,400 and ≈ 2,100 m. a.m.s.l. The discharge zone covers the basal part of the basin, culminating in the Lake itself. This is the most complex part of the basin in hydrogeological terms as the lake lies in the bottom of the rift valley.

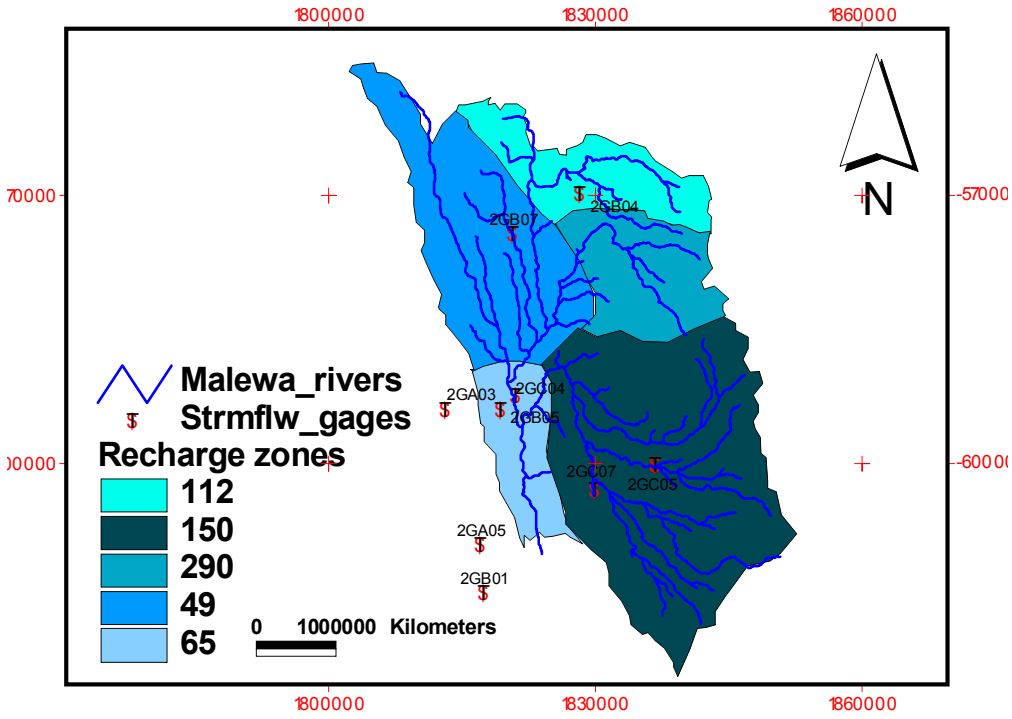


Figure 21: General recharge zonation map in mm/year:(Adapted from Graham, 1998)

The piezometric contours (Figure 22) indicate a development of sink on the North-Eastern side of Lake Naivasha around Three Point Farm and Manera Farms (Nabide, 2002).

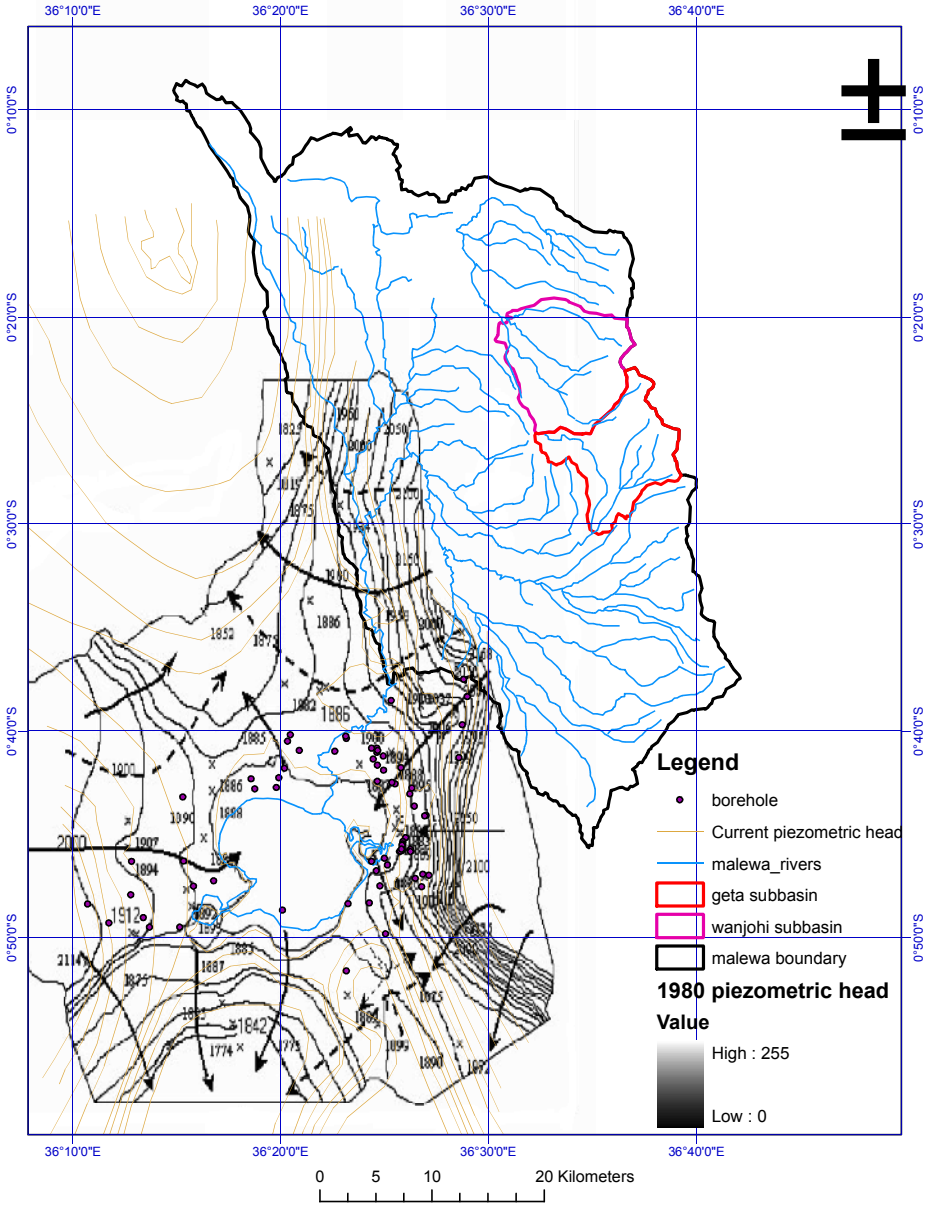


Figure 22: Current and 1980 Piezometric Head Contours. W indicates the depression due to extraction from the well field: (Adapted from Nabide, 2002).

There has not been a major change in the flow pattern since early 1980s to the present according to the 1980 piezometric contour map. There has been a fall in the piezometric heads in the North-Western part area around Three Point Farm and Manera Farm (point W in Figure 22), where over-abstraction of groundwater occurs (Owor, 2000) resulting into a cone of depression and hence back flow of groundwater from the lake itself. The piezometric head indicates that the middle catchment is where the problem is but since the main concern was to identify headwater as a priority area its significance is downplayed in the criterion for selection.

Two priority areas were selected based on the in-depth analysis of the indicated parameters. Overlaying the parameter (Figure 23), the resultant selected priority areas for implementing PES are shown in Figure 24.

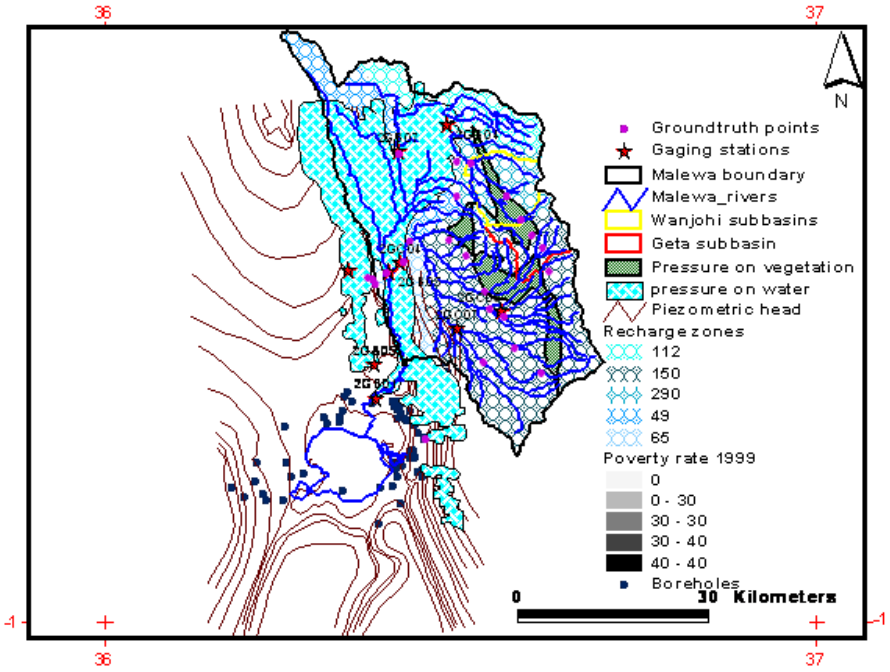


Figure 23: Overlay of parameters to determine the priority area for PES implementation

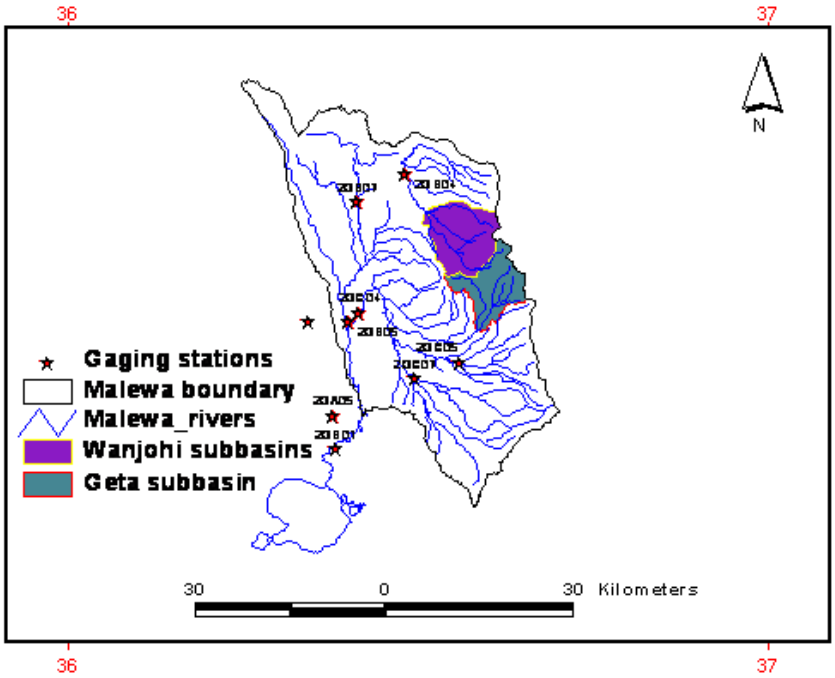


Figure 24: Selected priority areas for PES implementation

GETA sub-basin (Area1) =121km^2 and Wanjohi sub-basin (Area2) =112 km^2

4.0 Conclusion and Recommendations

4.1 Conclusion

From the demographic data, it can be inferred that accelerated erosion and excessive runoff are connected with development activities and human disturbances; clearance of fragile zones, denudation and compaction of soil through overgrazing, exhaustion of soil through intensive cropping. Erosion increases as a function of population density in a given agrarian system, if the population passes a certain threshold, land starts to run short, and soil restoration mechanisms seize up. One speaks of a densely populated degraded area when the population reaches 100inhabitants/km^2.

Two sub-basins were identified to be suitable for PES implementation. The GETA sub-basin covered an area of 121 km^2 and Wanjohi sub-basin covering an area of 112 km^2. The following parameters were used as a criterion for selecting the target sub-basins mean annual water yield, mean annual rainfall, population density, poverty density, sediment yield, water conflicts pressures on vegetation and water bodies and recharge/discharge zones.

The complexity of Malewa watershed makes implementation of PES tricky. The basin does not follow strictly the upstream-downstream user relationship. The over abstraction of water in the middle catchment complicates the relationship and within the same middle catchment, exist rainfall deficiency and this encourages irrigated agriculture practice resulting in overexploitation of groundwater.

4.2 Recommendations

Based on the lessons learned in this study some recommendations including proposed future work are listed below.

More climatological and hydrological monitoring stations need to be established in Malewa river basin especially in the upstream end for better results in hydrological studies. This is necessary since ground truthing is always needed even with estimations of satellite based rainfall data.

Future work ought to include estimation of water abstracted from upper catchments of Malewa River basin for current and future proposed projects. Although this was not part of the study it was noted that many sectors are competing for the limited amount of water available in Malewa River basin. Apparently potentials of such planned abstractions are not known. Agriculture being the main user (expansion of irrigated agriculture) can perhaps be one of the causes of reduced flows downstream with previous research showing a cone of depression in the middle catchment (Three point farm and Manera farms) which is another possible cause of reduction inn water levels of Lake Naivasha. This is vital for balancing water use in various sectors and avoiding conflicts between downstream and upstream water users.

References

Atkilt, G. (2001). Soil Survey to Predict Soil Characteristics Relevant to Land Management (Naivasha, Kenya). MSc Thesis. ITC. *Soil Science Division. Enschede*, pp 154.

Beck, M. B., Ravetz, J. R., Mulkey, L. A. and Barnwell, T. O., (1997). On the problem of model validation for predictive exposure assessments, *Stochastic Hydrology and Hydraulics*, **11**(3).

Santhi, C., Arnold, J. G., Williams, J. R., Dugas, W. A., Hauck, L. M. (2001a). Application of a watershed model to evaluate management effects on point and nonpoint pollution. *Transactions of the American Society of Agricultural Engineering*, **44** (66), pp 1559e1770.

Betch, R., and D., Harper. (2002). Towards an understanding of human impact upon the hydrology of Lake Naivasha, *Hhdrobiologia*, 488, pp 1-11.

Bhandari, A. K., (2005). Study to assess accurate spatial rainfall data in Lake Naivasha basin, Kenya, Enschede, ITC.

Chen, X., (2002). Using remote sensing and GIS to analyze land cover change and its impacts on regional sustainable development. *International Journal of Remote Sensing*, **23**(1), pp 107-124.

Clarke, M. C., G. D. G., Woodhall, D. Allen and G. Darling, (1990). Geological, volcanic and Hydrological Controls on the occurrence of geothermal Activity in the area surrounding Lake Naivasha, Kenya Ministry of Energy, Nairobi.

Congalton, R. G., et al., (1998). Mapping and monitoring agricultural crops and other land cover in the lower Colorado River basin. *American Society for Photogrammetry and Remote Sensing,* **64**(11), pp 1107-1113.

Daniel, J. G., Kulasingam, A. (1975). Problems arising from large scale forest clearing for agricultural use-the Malaysian experience. *Planter, Kuala Lumpur,* **51**, pp 250-257.

Duncan M. (2003). Clarification of the effect of vegetation change on water yield prepared for Environment Canterbury, technical report U03/81.

Farah, H.O., (2001). Estimation of regional evaporation under different weather conditions from satellite and meteorological data: A case study in the Naivasha basin, Kenya. PhD Thesis, Wageningen University, The Netherland.

Graham A., (1998). Groundwater recharge estimation of the Malewa catchment, Naivasha, Kenya, Enschede, ITC.

Hennemann, R. (2001a) Elective on Land Degradation, Assessment, Monitoring and Modelling. Soil Science Division, ITC, Enschede, The Netherlands.Hennemann, R. (2001b) Some Notes About Soil and Land Degrafdation in the Naivasha Rangeland Zone, pp. 3. Soil Science Division, ITC, Enchede, The Netherlands.

Inamdar, S (2004). Assessment of Modeling Tools and Data Needs for Developing the Sediment Portion of the TMDL Plan for a Mixed Watershed. Final Report to the Great Lakes Basin Program. Buffalo, New York, 10-12.

Kamoni, P. T. (1988). Detailed soil survey of a part of quarantine farm-National Husbandry Research Station, Naivasha, Nakuru District, pp. 24. Kenya Soil Survey, Nairobi.

Kiai, S. P. M. and Mailu, G. M. (1998). Wetland classification for agricultural development in Eastern and Southern Africa. FAO, Harare, Zimbabwe.

Motovilov, Y., L.Gottschalk, K.Engeland, A.Rodhe (1999). Validation of a Distributed Hydrological Model against Spatial Observations. *Agricultural and Forest Meteorology* 98-99, 257-277.

Muthuwatta, P. L., (2004). Long term rainfall-runoff-Lake level modeling of the Naivasha Basin, Kenya, Enschede, ITC.

Nagelhout, A. (2001) Performance Analysis of Small Format Aerial Photography (SFAP) in Assessing Current Status and Trends in Wind Erosion: A case study in the Longonot-Kijabe Hill Area, Naivasha District, Kenya. MSc thesis, ITC.

Nash, J. E. and Sutchliffe, J. V. (1970). River flow forecasting through conceptual models, Part I-a discussion of principles, *J.Hydrol.* **10**, pp 282-290.

Neitsch, S. L., J. G. Arnold, J. R. Kiniry, R. Srinivasan, and Williams, J. R. (2002). Soil and Water Assessment Tool Users Manual: Version 2000. GSWRL Report 02-03, BRC Report 02-07, Published by Texas Water Resources Institute TR-193, College Station, TX.

Ojiambo, B. S., (1992). Hydrogeologic, Hydrochemical and Stable Isotopic Study of Possible Interactions Between Lake Naivasha, Shallow Subsurface and Olkaria Geotherma.

Owor, M. (2000). The Long-term interaction of Groundwater with Lake Naivasha, Kenya : A numerical simulation of the relationship between groundwater and lake allowing for fluctuating lake levels. MSc-Thesis, ITC, Enschede, pp 110.

Pagiola, S., and Platais, G. (2003). Implementing Systems of Payments for Environmental Services: Initial Lessons of Experience. Paper presented at the Workshop on Ecosystem Services in the Tropics: Challenges to Marketing Forest Function, Spring 2003 Meeting of the International Society of Tropical Foresters, Yale University, April 5-6, 2003.

Paruelo, J. M., Burke, I. C., and Lauenroth, W.K., 2001. Land-use impact on ecosystem functioning in eastern Colorado, USA. *Global Change Biology,* **7**, pp 631-639.

Rahim, A. N. (1987). The impact of forest conversion on water yield in Peninsular Malaysia. Paper presented at the workshop on impact of operations in natural and plantation forest on conservation of soil and water resources. Serdang. pp. 2326.

Robert, B. and Sarah, H. (2003). Sharing experience and early lessons in GEF and non-GEF lake basin management projects Lake Naivasha brief Prepared for the ILEC foundation of Japan, October 2003.

Rykiel, E. J., (1996). Testing ecological models: the meaning of validation, Ecological Modeling, 90: 229-244.SAF, (2004) Loss of forest land. A position statement of the society of American foresters Retrieved on December 07, 2006, from http://www.safnet.org/policy and press/psst/loss-of-forest-land.cfm

Salah A., (1999). Sustainable use of water among competing sectors: A study in the Naivasha catchment, Rift Valley Province, Kenya, Enschede, ITC.

Siderius, W. (1998). Soils of The Lake Naivasha Environs. In: Contribution to the article in ITC journal, pp. 8. Soil Science Division, ITC, Enshede, The Netherlands.

Sombroek, W. G., Braun, H.M.H. and van der Pouw, B. J. A. (1980). The explanatory soil map and agro-climatic zone map of Kenya. Report No. E.I, Kenya Soil Survey, Nairobi, 56 pp.

Van Liew, M. W., and J. Garbrecht. 2003. Hydrologic simulation of the Little Washita River Experimental Watershed using SWAT. *J. Am. Water Resour. Assoc.*, **39**(2), pp 413-426.

Wischmeier, W. H., and Smith, D. D. (1978). Predicting rainfall erosion loss: A guide to conservation planning. Agricultural handbook 537. U. S. Department of Agriculture, Washington, D.C.

ACCESS TO SAFE DRINKING WATER AND WATER-BORNE DISEASES IN MASABA NORTH DISTRICT, KENYA

J. M. Nyagwencha, J. W. Kaluli, P. G. Home and H. Murage
Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya

Abstract
Consumption of contaminated water is a major cause of illness in the world and particularly in rural communities, especially in developing countries like Kenya. The objectives of this cross-sectional study were to evaluate access to safe drinking water, water purification techniques and water-borne disease incidence in Masaba North District. Some 100 households were randomly selected with structured interview questions being administered to 25 households in each of the four divisions in the District. Water testing was carried out in a make-shift laboratory using the Oxfam DelAgua kit to determine the number of *E. coli* colony forming unity (CFU) per 100ml while a hach turbidimeter was used to measure water turbidity. It was found that a high percentage of the households had access to 'improved' water sources including protected springs (79%) with 64% of the households boiling their water before consumption.. Only 17% of the households had access to water free from fecal contamination. The most effective method of purification was Biosand filtration which provided 57% reduction in turbidity and 92% reduction in *E. coli.* Out of the 100 households, 20% households indicated that at least one member of the household had suffered from water-borne diseases in the past year. Whereas many households can easily access improved water sources, access to safe drinking water was still a major challenge. Further more, water from "protected sources" was not necessarily safe for drinking. There was inconsistent and inadequate utilization of water purification techniques leading to consumption of contaminated water even after purification had been carried out.

Key words: Water treatment, boiling, chlorination, biosand filtration, solar disinfection

1.0 Introduction

A large proportion of world population does not have access to safe and clean water. According to the World Health Organization, 1.1 billion people in the world's population- lack access to safe drinking water (WHO, 2004). As a result of this, 1.8 million people die every year from diarrhoeal diseases (including cholera); 90% being children under 5, mostly in developing countries.

The most commonly used method of water purification in rural Kenya is boiling (UNICEF, 2008). However, due to overdependence on unsustainable sources of energy such as biomass and the problems associated with their use including indoor air pollution, most households who profess to use this method for purification do not use it consistently leading to consumption of unsafe water. Another commonly used method of purification is biosand filtration which has to be proved an effective simple, inexpensive and reliable (Collins *et al,* 1992). The advantage of Biosand filtration is that it can be locally built, using locally available materials, it is easy to maintain, and does not require any energy input and is relatively inexpensive (Duke *et al.,* 2006).

Chlorination is the second most widely-practiced means of treating water at the community level, (UNICEF, 2008). There are however concerns about the taste and odour of chlorinated water with some consumers finding it objectionable. However, some studies show that this is probably exacerbated by a tendency to add more than the recommended dose of chlorine (Gurian *et al.,* 2006).

Solar disinfection, which combines thermal and UV radiation, has been repeatedly shown to be effective for eliminating microbial pathogens and reduce diarrheal morbidity (Hobbins, 2003). However, studies show that this method has many limitations ranging from the obvious fact that it is dependent on weather conditions and high turbidity and particulate materials absorb UV rays (Qualls *et al.,* 1983).

Whereas access to 'improved' water sources has increased rapidly in the last decade, little has been done to find out whether this increase in access to 'improved' water sources has led to an increase in access to safe drinking water. This research was therefore carried out with the objective of evaluating access to safe drinking water, water purification techniques and water-borne disease prevalence in Masaba North District.

2.0 Materials and Methods

2.1 Study Area and Population

For this study, participating households were situated in four different regions, i.e. in East Kitutu Division, Gesima Division, Gachuba Division and Mochenwa Division. From each of these four divisions, 25 households were randomly selected to make a total of 100 households in which the research instruments were administered.

2.2 Water Sampling and Testing

Sterilized plastic bags were used to collect water samples from each of the 100 sampled households. From each household, water samples were collected from drinking water from the source and another sample from stored drinking water after intervention. About 500 ml of water sample from each source was collected, labeled and kept in an icebox during transportation and analyzed in the laboratory to determine fecal coliforms (*E. coli*) as well as turbidity. The samples were tested within 6-8 hours of collection (WHO, 2006).

The number of *E. coli* present in each sample was determined using the Membrane Filtration Method. This method, which is best suited to laboratory conditions, has been modified to adapt to field conditions in the DelAgua kit. Samples taken were allowed to recuperate for a minimum of 1

hour, cultured on membrane lauryl sulphate broth and enumerated after 16-18 hours of incubation at 44.5°C (+/- 0.5°C), (Earwaker, 2006). Negative controls, i.e., 100 ml contamination of water after collection of sterile distilled water, were processed after every twentieth sample to ensure that the equipment had been adequately sanitized (Rufener *et al.,* 2008).

The turbidity of each water sample was tested using the HachTurbidimeter. The HachTurbidimeter was preferred over other commonly used instruments of measuring turbidity, notably the DelAgua Turbidimeter, because it is more accurate, faster and precise. The Turbidity was measured in NTU, with values below 5 NTU considered safe for drinking (WHO, 2008).

2.3 Water Sources, Purification Methods and Water-Borne Diseases

The individual most responsible for management of drinking water in the household, in most cases the mother, was identified and interviewed. Where this was not possible, the next most responsible person was interviewed. Water sources, purification methods and health data were identified through a questionnaire with structured questions administered with the help of two trained research assistants. Questions asked touched on distance to water sources, time taken to collect water, methods of water purification, sources of water and water-borne disease incidence.

3.0 Results

3.1 Drinking Water Sources

Many of the households sampled in the District got their drinking water from 'improved' water sources (protected spring, piped water, protected dug well and borehole). Only 18% of the households sampled got water from unimproved sources such as unprotected dug well, surface water and unprotected springs (Figure 1). However, 31 households reported that their major water source was seasonal while the other 69 households reported that their major water source was permanent.

A majority of these water sources were within 1 km or less from the households sampled. Out of the 100 households, 79 got their drinking water from within 500 m distance while 8 households walked for more than 1 km to access their main source of drinking water (Figure 2). Some 43 households spent less than 1 hour daily to collect their drinking water, 53 spent between 1 and 2 hours while another 4 households spent more than 2 hours to collect water daily.

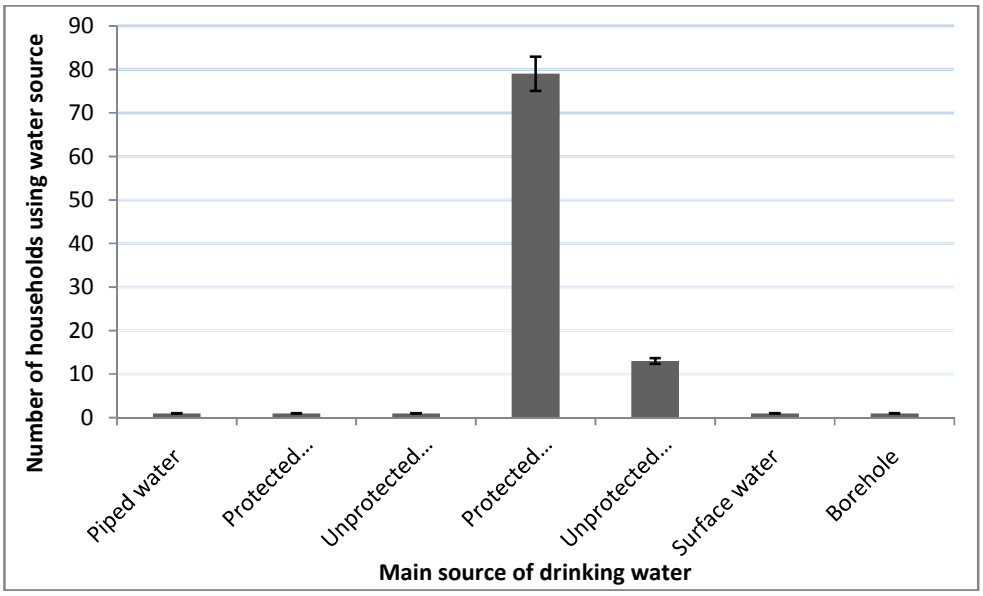


Figure 1: Major sources of drinking water in Masaba North District

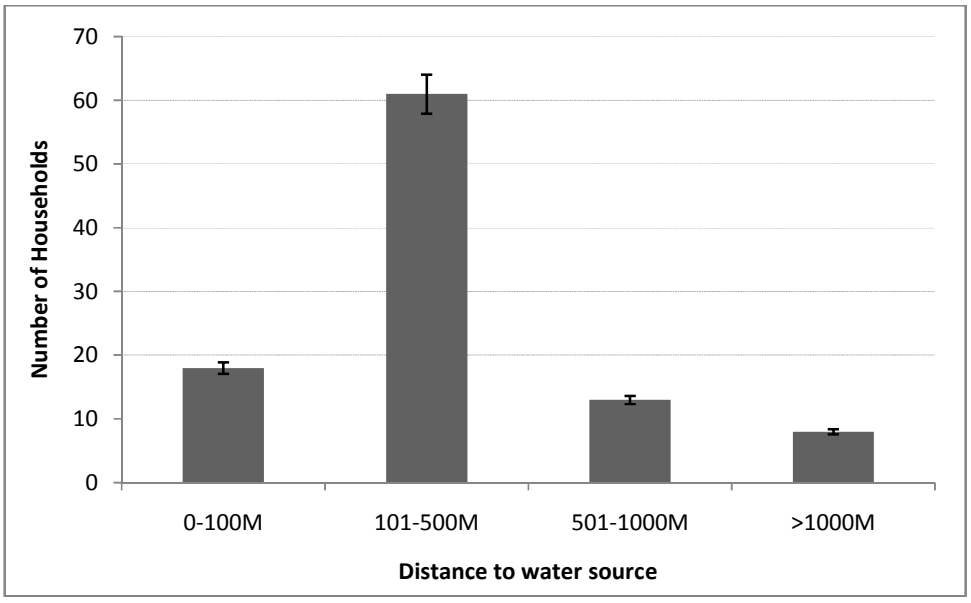


Figure 2: Distance to water sources

3.2 Water Purification Methods

The commonly used water purification technologies in the district included boiling (64%), disinfection using chlorination (4%), biosand filtration (3%) and cloth filtration (3%), while 26% of the population did not purify their water (Figure 3). Some 14% of the households could not remember when they last purified their water using their preferred method while another 3% had used their method more than a week before. The most preferred method of water purification was chlorination (41%) with only 1% indicating that they prefered boiling most.

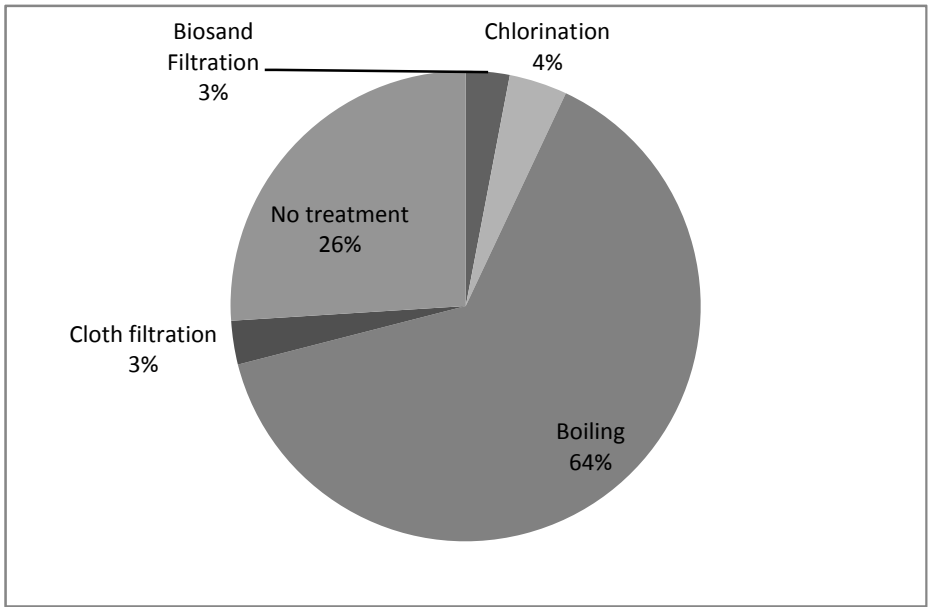


Figure 3: Water purification methods in Masaba North District

3.3 Drinking Water Quality

Out of the 100 sampled households, 26 households did not purify their water while 12 households that claimed to purify their water before consumption did not have any treated water readily available for testing.

Only 17 households achieved the recommended 0 CFU per 100 ml in their drinking water while 50 households had 1-100 CFU/100ml and 21 households had 101-1000 CFU/100 ml in their drinking water. For the turbidity tests, 71 households achieved the WHO recommended standard of less than 5 NTU while the household with the highest turbidity in drinking water had 12.3 NTU (Figure 4).

All methods showed a general reduction in turbidity with biosand filtration showing the highest reduction of 57%. The same method also showed the highest reduction in colony forming unity (CFU) of 92%. .

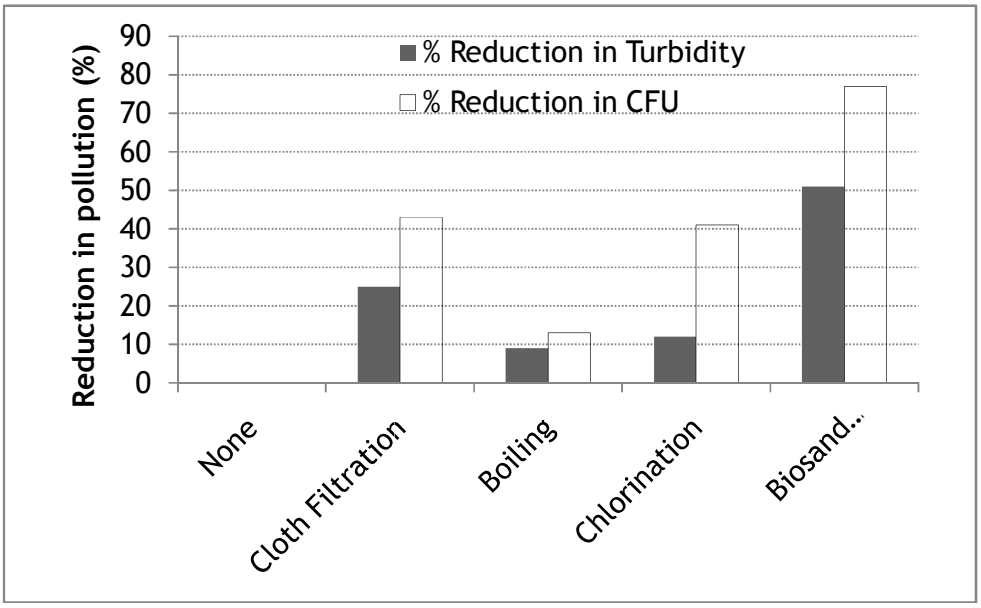


Figure 4: Effectiveness of water purification methods

3.4 Water- borne Diseases

Typhoid most commonly reported water-borne disease in the district, as13% of the households reported that at least one family member suffered from the desease in the past one year. Amoeba was the second-most widely reported disease at 3%, while 4% of the households reported that there had been both typhoid and amoeba in the household in the past year. Majority of households did not report that anyone in the household had suffered from any disease related to consumption of poor water quality (Figure 5).

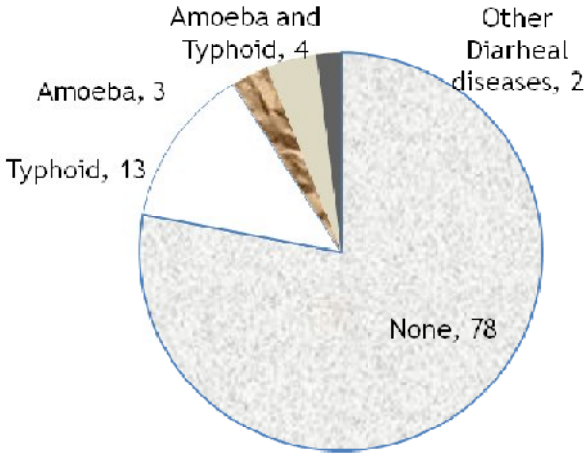


Figure 5: Number of households reporting Water-borne diseases in Masaba North District

4.0 Discussion and Conclusions

A high percentage of the households had access to 'improved' water sources including protected springs (79%). However, many households identified their water sources as unreliable with 31% indicating that their main water source was seasonal. This may lead to use of water from other sources, especially during the dry season, which may be of poorer quality than the main source. Only 1% of the households sampled had access to piped water due to the fact that the district is predominantly rural. Many of the households lived less than 1 km away from their main water source with only 8% indicating that their main source of drinking water is more than 1 km away. This can be attributed to the fact that the district is in a high altitude region with high rainfall and many springs.

The most commonly used method of water purification was boiling which mostly relies on non-renewable sources of energy such as charcoal and firewood. These materials were not always available and as a result households fail to purify their water, exposing themselves to water-borne diseases. Majority of households consider chlorination to be the most suitable method of water purification. This can be attributed to the fact that chlorination is considered a much faster, cheaper and convenient alternative, although its unavailability in this rural district has led to minimal use.

Only 17% of the treated water samples met the WHO/KEBS recommended standard of 0 CFU/100ml for drinking water (WSREB, 2007; WHO, 2006). This low turn out can be attributed to several factors including inadequate treatment, recontamination due to poor storage and long periods of drinking water storage. Another 17% of the households were found to consume water above the 5 NTU recommended by WHO.

The poor results from boiling could be due to the fact that there is no residual disinfectant in boiled water, longer period of water storage increasing the likelihood of recontamination or inadequate boiling. The major challenge in boiling was lack of consistency with 14 households who claimed to use the method not able to recall when the method was last used. The better results obtained from households using chlorination can be explained by the presence of residual disinfectant (Rufener *et al*., 2008) while those from biosand filtration could be due to the fact that water treatment is carried out everyday leading to shorter periods of water storage.

Reduction in turbidity for households using methods of water purification such as boiling and chlorination which do not reduce turbidity was due to the fact that the samples tested were of stored water where settling of sediments had taken place leading to a reduction in the turbidity of the stored drinking water.

In the past one year, 20 households reported at least one household member having suffered from a water-borne disease. This is not surprising especially since the water quality tests indicated that only 17% of the households consume water which can be classified as safe.

Further research needs to be done to ascertain the sources of recontamination of treated water in the district, the most appropriate duration of drinking water storage in respect to each method and ways through which the government and development partners can promote use of such methods as chlorination and biosand filtration, which may be more appropriate than boiling.

In conclusion, whereas many households could easily access improved water sources, access to safe drinking water is still a major challenge. There was inconsistent and inadequate utilization of water purification techniques leading to consumption of contaminated water even after purification had been carried out. There's need to promote more economically and environmentally viable water purification methods, sensitize households about hygiene and sanitation practices aimed at reducing

drinking water re-contamination which will ultimately help in increasing access to safe drinking water and reduce the high incidence of water-borne diseases in the district.

Acknowledgement
The authors are grateful for the invaluable support of Aqua Clara International who partially funded this research. Gratitude is also due to the households of Masaba North District who sacrificed their time to participate in this study and whose contribution has made all this possible.

References

Collins, R., Eighmy, T., Fenstermacher, J. and Spanos, S. (1992), *Removing Natural Organic Matter by Conventional Slow Sand Filtration*; *Research and Technology Journal*. Denver, Colorado USA.

Duke, W., Mazumder, A., Nordin, R. and Baker, D. (2006). The use and performance of Biosand Filters in the Artibonite Valley of Haiti: A field study of 107 households. *Rural and Remote Health,* **6**, pp 570.

Earwaker, P. (2006). Evaluation of Household BioSand Filters in Ethiopia. Cranfield University.

Gurian, P. L., Camacho G., Jun-young P., Steve R. C. and Kristina, D. M. (2006) Evaluating in-home water purification methods for communities in Texas on the border with Mexico*. Public Health,* **20**(6), pp 403–6.

Hobbins, M. (2003). The SODIS health impact study *(*Ph.D. Thesis). Swiss Tropical Institute, Basel.

Qualls, R. G., Flynn, M. P., and Donald J.J. (1983). The Role of Suspended Particles in Ultraviolet Disinfection. *Water Pollution Control Federation*, **55,** pp 1280-128.

Rufener S., Mäusezahl D., Mosler H., and Weingartner R. (2008). Quality of Drinking-water at Source and Point of consumption Drinking Cup As a High Potential Recontamination Risk: A Field Study in Bolivia. *Health Population Nutrition*, **28**(1), pp 34-41.

NICEF (2008). Promotion of Household Water treatment and safe storage in UNICEF WASH programmes. New York, UNICEF.

Water Services Regulatory Board (2007). Drinking water quality and Effluent Monitoring Guidelines. Nairobi: WRSB Publishing, Nairobi.

World Health Organization (WHO) 2006 Guidelines for Drinking-water Quality, First Addendum to the 3rd Edition, Volume 1, Recommendations. World Health Organization, Geneva.

SURFACE WATER QUALITY IN KENYA'S URBAN ENVIRONMENT: A CASE STUDY OF GITHURAI, NAIROBI, KENYA

J. W. Kaluli, C. Wageci and P. G. Home
Biomechanical and Environmental Engineering Department, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya

Abstract
Safe, clean drinking water and sanitation facilities are key to economic development and public health in Kenya. Rapid urbanization and population growth mean worsening conditions for millions of Kenyans, especially the poorest. Sanitation is one of the greatest problems especially in the informal settlements where 60% of the people in the urban centers reside. In fact, 50% of all preventable illnesses in Kenya are water, sanitation and hygiene related. This study was done to establish the level of indicator water quality parameters, and establish water borne disease prevalence in Githurai and adjacent communities. Water samples were collected from 6 points distributed uniformly along Kiu River in Githurai. Using standard methods, the samples were analyzed for Dissolved Oxygen (DO), BOD, TSS and TDS in the JKUAT environmental laboratory. A survey was also done in Githurai, Kahawa Sukari and Kahawa Wendani to establish the prevalence of water borne diseases. Data was collected from local medical clinics and Ruiru District Public Health Office. Randomly selected individuals were also interviewed to establish the frequency of visits to health facilities**.** The study revealed that dissolved oxygen in surface water was between 1.5 and 8.5 mg/L while biochemical oxygen demand (BOD) was between 200 and 400 mg/L. This was much higher than NEMA standards for surface water which demand that the BOD of any effluents to be discharged into surface water should be less than 30 mg/L. Total suspended solids (TSS) varied from 900 to 950 mg/L. NEMA allows domestic water not to have TSS of more than 30 mg/L. Total dissolved solids (TDS) were in the range of 3000 to 9000 mg/L compared to a maximum of 1200 mg/L which is allowed by NEMA. Surface water in Githurai is highly polluted and poses public health risks. Some 30-40% of all patients visiting hospitals in the study area suffered from diarrheal diseases and the average resident in Githurai was treated for water borne diseases once every three months. Therefore, an urgent intervention is required to clean up Kiu River and stop further contamination of the river.

Key words: Sanitation, informal settlement, water quality, BOD, TSS, TDS

1.0 Introduction

Water is a scarce commodity in Nairobi, and the little that is available often gets polluted as a result of various human activities. Therefore, as is the case in many other cities in the world, Nairobi is experiencing a steady decline of available freshwater. This is because there is also a steady increase in population. Urban population often grows as a result rural-urban migration by people looking for better living standards (Grau and Alde, 2007). Populating urban areas reduces the land use pressure in fragile rural ecosystems, but results in environmental pollution when the production of human waste increases. Therefore, appropriate interventions are required to manage the wastewater, ensure public health protection, and guard against pollution of scarce water resources; and if possible reduce pressure on scarce freshwater resources (Bakir, 2000).

Githurai is a highly populated suburb of Nairobi City. It is located in the Northern outskirts of Kenya's Capital City. This area has experienced population increase without corresponding planning and infrastructure development. The rapid urban population growth is characterized by poor sanitation, environmentally related infections, as well as psychological and social illnesses (Choldin, 1978). Sanitation improvement usually results in reduced cases of water related diseases. By increasing sewerage coverage from 26% to 80% of the households, Brazil reduced diarrhea among children under the age of three, by 22% (Nelson and Murray, 2008).

Informal settlements accommodate 60% of Kenya's urban population (Antao, et al., 2007). Although Githurai is not classified as an informal settlement, it has characteristics of an informal settlement. It discharges wastewater without any form of treatment; industries in Githurai discharge effluents that do not comply with Kenya's standards for discharge into the environment; and the wastewater is allowed to either percolates into the ground where it contaminates groundwater or flows into the natural drainage system causing surface water pollution. Because of this contamination of water resources, water related diseases are common. Out of the common diseases found in developing countries, 70% of them are related to water and sanitation (Antao, et al., 2007). The purpose of this study was to assess the public health situation in Githurai, which is a suburb of Nairobi City. Specific objectives for this study included assessing Kiu River water quality relative to Kenya's water quality guidelines; and evaluating the prevalence of water related diseases in Githurai.

2.0 Materials and Methods

At the Municipal Council of Ruiru population, domestic water supply and sanitation data were obtained. During the wet season, October to December 2009, surface water quality measurement in Githurai was assessed by taking sample along the river, starting from the point where the river enters Githurai from Kiambu (Figure 1), to a point 1 km east of point where the river crosses Thika road. A survey was done in Githurai area to identify suitable and representative sampling points, at places which were accessible on foot. Sampling points 1-3 were located West of Thika Road, while sampling points 4-6 were located to the east of Thika Road. Using a GPS system the coordinates of sampling points were established.

Sampling was carried out at each point in the mid morning. Using sterilized sampling bottles, two samples were collected at each sampling point. This was to ensure that the data obtained was representative of the pollution level at the sampling station. Using standard methods, the water samples collected were analyzed for turbidity, pH, dissolved oxygen, ammonia, nitrates, phosphates, coliform count, and electrical conductivity. The pH and electrical conductivity (EC) were measured with the help of a combined EC and pH meter. An EC meter measures the electrical conductivity of the water. While clean water has a low EC, water that is contaminated with nutrients has relatively higher EC.

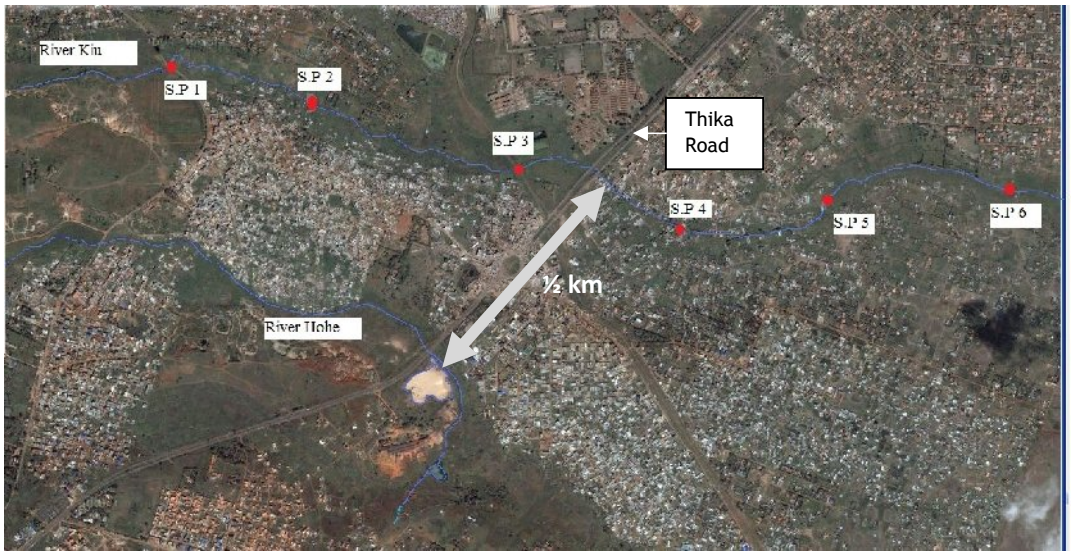


Figure 1: Aerial photograph of the project site

Total Suspended Solids (TSS) was determined by filtering 100ml of sample through a glass-fiber filter paper by the help of a suction pump. The weight of the evaporation dish plus filter was obtained. The trapped material (residue) was dried at a temperature of 180 ^{o}C in a porcelain dish for 24 hours. Cooling of the residue was done in dry desiccators, for 30 minutes. The obtained residue was weighed on an analytical balance and the results recorded.

Total Dissolved Solids (TDS) was determined by passing 100 ml of a sample through a filtering unit and drying of the filtrate done in the oven at 180 ^{o}C to dryness for 24 hours. Cooling in dry desiccators was done for 30minutes and the resulting residue was weighed on an analytical balance. The results were thus recorded.

Nutrients such as nitrogen and phosphorus, the 5 day Biological Oxygen Demand (BOD_5) and dissolved oxygen were measured using standard methods. By dipping the pH meter probe in half of 100ml of sample, stirring continued and steady pH reading obtained.

Nephelometric Method, using a turbidity meter, was used for the measurement of turbidity. The turbidity meter probe was dipped in half of 100 ml of sample, stirring continued and turbidity meter reading obtained in NTU units.

The electrical conductivity (EC) was determined by dipping the EC meter probe in half of 100ml of sample, string continued and steady EC reading obtained. A survey was done in Githurai, Kahawa Sukari and Kahawa Wendani to establish the prevalence of water borne diseases. Data was collected from local medical clinics and Ruiru District Public Health Office. Randomly selected individuals were also interviewed to establish how frequently they visited health facilities for treatment of diarrheal diseases**.**

3.0 Results and Discussion

The Kenya Water regulations state: "*Every person shall refrain from any act which directly or indirectly causes, or may cause immediate or subsequent water pollution… and No person shall throw or cause to flow into or near a water resource any liquid, solid or gaseous substance or deposit any such substance in or near it, as to cause pollution"* (Government of Kenya, 2006). In Githurai, this regulation is violated as is evidenced by the surface water quality.

3.1 Surface Water Pollution in Githurai

Water pollution is the contamination of water by undesirable foreign matter. One category of water pollutants is oxygen-demanding wastes; wastes that can be decomposed by oxygen-requiring bacteria. As the river entered Githurai, the concentration of dissolved oxygen was between 7 and 8.3 mg/L and as the final sampling point DO was about 3.3 mg/L. According WHO standards for drinking water resources, the minimum level of dissolved oxygen should be 4 mg/L. The reduced levels of dissolved oxygen (Figure 2) occurred probably as a result of increasing quantities of oxygen demanding wastes in the water. BOD_5 was about 30 mg/L as the water entered Githurai, 1 km West of Thika Road compared to more than 300 mg/L at SP6, 1 km East of Thika Road (Figure 2).

Increasing BOD indicated that there was an increase in organic substances as the river entered Githurai. This likely happened due to discharge of raw sewage into the river (Figure 2). These findings are similar to the data of Antao, et al, (2007) who found high pollutant levels in Ruiru River, a neighboring river with a similar environment. Pollution in surface water makes it a significant source of water-borne diseases.

Figure 3: Domestic wastewater flowing in open ditches which finally discharge into Kiu River

The average BOD at sampling point SP6 was 250 mg/L (Figure 2), and the streamflow was estimated as 100 L/s. It was also estimated that the distance from SP1 to SP6 was 2 km, and that the average width of the area contributing flow and pollution to the river was 2 km. Therefore the area contributing towards pollution of Kiu River up to SP6 was estimated as 400 ha. From census data obtained in the Ruiru District office, the population of Githurai is estimated as 100,000 people.

$$\text{DOD per day } (\text{——}) = 250 \text{—} * 100 - * 3600 * 24 \text{—} * \text{————} \quad \text{..... (1)}$$

$$(\quad) = \quad * 365$$

$$(\quad h \ ) = \frac{(\quad}{400\ h} \quad \text{..... (2)}$$

$$(\quad) = \frac{(\quad)}{,} \quad \text{..... (3)}$$

$$\text{..... (4)}$$

Using the formulas above, the annual BOD production per unit area in Githurai was calculated as 2.0 Tonnes/ha per year and BOD contribution per capita was 8 kg per year (Table 1). Lake Victoria, with an area of 4.87 million ha, a population of 1 million people, contributes 7510 Tonnes of BOD per year (Scheren et al., 2000). This works out to BOD production of 1.5×10^{-3} Tonnes/ha or 8 kg/capita/year. The high loading of BOD in the surface water of Githurai is probably because the area lacks a sewer system. Individual properties use septic tanks for wastewater treatment. Apparently these wastewater treatment systems have inadequate facilities to handle human waste from the large Githurai population. Most home owners end up discharging virtually untreated sewage into open ditches which finally discharge into Kiu River, thus becoming a source of contamination. According to the calculations done above, BOD production per unit area in densely populated urban areas such as

Githurai was more than 1000 time more than it was estimated to be in a rural area. This is likely because untreated wastewater in Githurai was discharged into the surface Kiu River. Mohammed (2002) found that coastal waters in the vicinity of Dar es Salaam harbor were heavily polluted by wastewaters that are discharged into the ocean without any form of treatment. The same study found that surface water in Dar es Salaam received about 56 Tonnes/day of BOD.

Table 1: BOD production in Githurai compared to a rural area

Parameter	*Githurai*	*Rural area (Lake Victoria Basin)*
BOD production (Tonnes/ha/year)	2.0	0.0015
BOD production (kg/capita/year)	8	8

Failure to treat wastewater before discharge results in the pollution of surface water bodies. This is the case in Githurai, and necessary interventions are required to collect and treat wastewater before discharge into the environment.

3.2 Solids in the Surface Water of Githurai

Suspended and dissolved solids are pollutants that can find their way into surface water bodies. In Kiu River, suspended solids varied between 910 and 960 mg/L (Figure 4). The upper limit for effluent discharge into surface water bodies is 30 mg/L of suspended solids (Government of Kenya, 2006), which would allow the discharge of about 260 kg/day of solids. The TSS of 960 mg/L allows over 8,000 kg/day of solids. The City of Dar es Salaam has recorded pollution, in term of suspended solids, of up to 78,429 kg/day (Mohammed, 2002). Although the situation in Githurai is not as bad as in Dar es Salaam, the right interventions should be taken to avoid this pollution of surface water bodies.

The concentration of dissolved solid increased from upstream to downstream with the highest concentration being nearly 9,000 mg/L close to SP6 where the electrical conductivity was about 400 µm/cm (Figure 4 and Figure 2). Irrigation water should not have TDS of more than 1200 mg/L (Republic of Kenya, 2006). Therefore, Kiu River water seems is to be unacceptable for agricultural use.

Nutrients in water form another class of water pollutants, including water-soluble nitrates and phosphates that cause excessive growth of algae and other water plants, and deplete oxygen supply in water. In the presence of nutrients, certain aerobic bacteria become more active and deplete oxygen levels even further, so that only anaerobic bacteria can be active. This makes life in the water impossible for fish and other organisms. Nitrates in drinking water can harm the health of young children. As Kiu River runs along the populated parts of Githurai, the concentration of nutrients increases. The maximum concentration (about 2.9 mg/L of Total Nitrogen and 3 mg/L of Phosphorus) was reached near sampling point SP6 4 (Figure 5). NEMA has no guidelines for maximum levels of nutrients in effluent for discharge into surface water bodies. However, drinking water should not have more than 10 mg/L of Nitrates. The amount of nutrients in this case appears to be low, perhaps because the amount of agricultural and industrial activity is not sufficient to elevate nutrient levels in surface water.

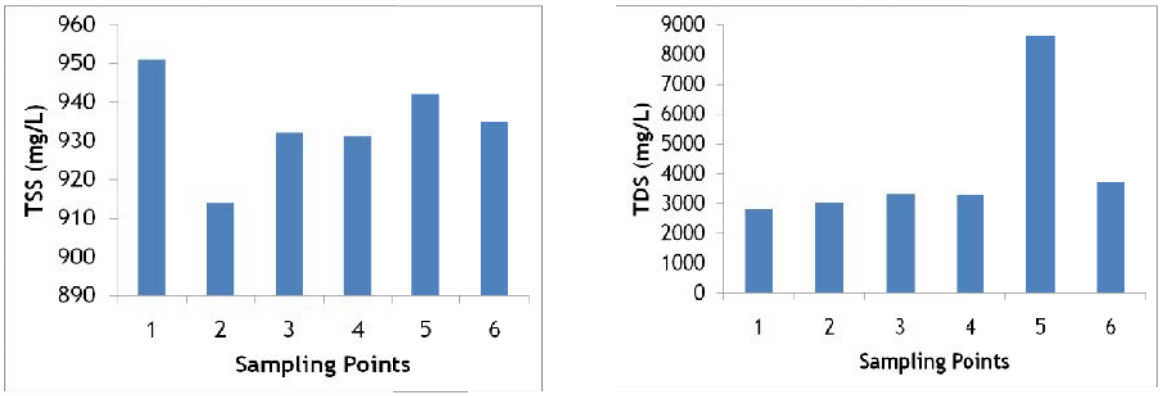


Figure 4: Dissolved and Suspended solids in Kiu River water

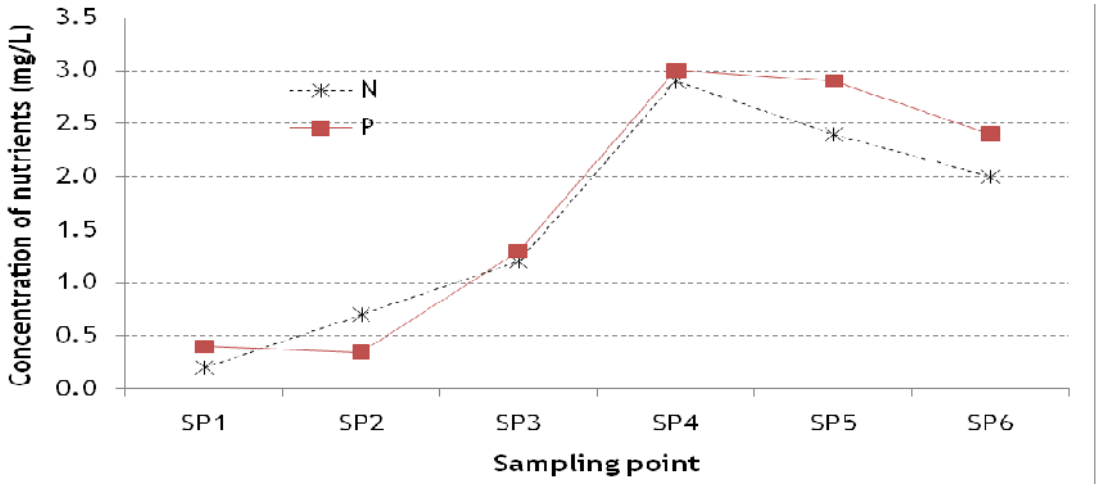


Figure 5: Nutrients in Kiu River water

During the study period, it was observed that solid waste was allowed to accumulate and release leachate with organic pollutants. This was particularly the case in the open air market and residential areas. What is more, solid waste was frequently dumped into surface drainage ditches, meaning that all fluids released from the solid waste ended up in Kiu River.

Wherever BOD concentration is high, disease-causing agents such as bacteria, viruses, protozoa and parasitic worms are likely to also be present. Coliform bacteria, indicating the presence of disease-causing agents were detected at all sampling points. According to NEMA, water to be used for the irrigation of restricted crops should have less than 1000 MPN/100 ml of coliform bacteria (Government of Kenya, 2006). In this study the population of coliform bacteria detected was $120x10^6$ MPN/100 ml of water. Therefore Kiu River water must be treated before being used for any purpose especially irrigation.

3.3 Water- Related Diseases in Githurai

Only 53% of low income residents in Ruiru District have access to treated drinking water (Antao, et al., 2007). This means that the low income population faces much higher public health risks than the rest of the population.

Many Githurai residents often complain of malaria, diarrhea and intestinal worms. These infections are mostly caused by ingesting contaminated water. Diarrhea is a leading cause of death in children. According to the Public Health Office in Ruiru District, where Githurai is located, in year 2010 the majority of cases with diarrheal diseases (typhoid, amoebiasis, etc) were between 30 and 40% of all

the patients seeking medical care. Unlike diarrheal diseases, Malaria was highest during the wet months of the year and was lowest during May, June and July when it was relatively dry (Figure 6). Most likely, malaria was high during wet weather because of the enhanced breading of mosquitoes. However, because diarrheal diseases are connected with the state of cleanliness, their occurrence tended to be independent of weather conditions. Among poor families in Brazil, Sobel, et al., (2004), found childhood diarrheal morbidity in children aged 1–4 years to be a problem. They suggested that it was necessary to boil baby bottles and bottle nipples, and that care givers needed to observe hygienic preparation of fruit juices.

The rate of hospital visits because of water borne diarrheal diseases was most frequent in Githurai where on average person was treated once every 3 months (Figure 7). In Kahawa Sukari, which is a more affluent residential area, the average resident was treated for diarrheal diseases once every 3.5 year while in Kahawa Wendani the time interval between hospital visits was 2 years.
Infection with intestinal worms was less frequent. In Kahawa Sukari and Kahawa Wendani residents completed 5 years without worm infections. In Githurai these infections occurred once in 4 years. The rate of malaria occurrence was similar to that of diarrheal diseases. In Githurai people complained of Malaria once every 1.5 years while in Kahawa Sukari and Kahawa Wendani the complaints were reported once every 3.5 year and 2 years, respectively.

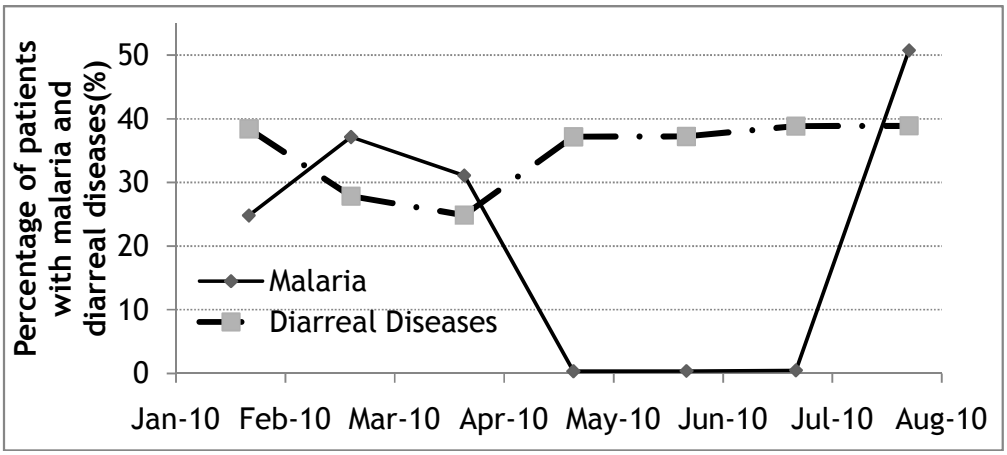


Figure 6: Water-related disease occurrence during the study period

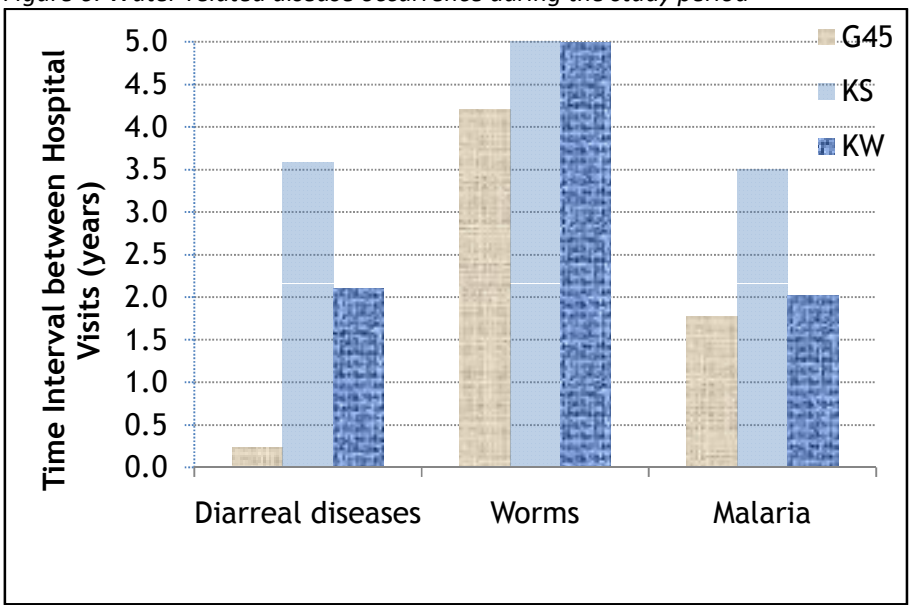


Figure 7: Time interval between hospital visits

4.0 Conclusions and Recommendations

(i) As Kiu River entered Githurai the BOD was 30 mg/L but before leaving the area, it had BOD of 300 mg/L, indicating that pollutants were injected into the river within Githurai.

(ii) BOD production in Githurai is about 8 kg/person/year, a figure which is comparable to the rate of BOD production in Lake Victoria region.

(iii) Kiu River water had over 1200 mg/L of TDS, and was therefore considered unacceptable for agricultural use.

(iv) Some 30-40% of all patients visiting hospitals in the study area suffered from diarrheal diseases.

(v) The average resident in Githurai gets treated for water borne diseases once every three months. Therefore, an urgent intervention is required to clean up Kiu River and stop further contamination of the river.

References

Antao, C., H. Bonner, J. Franco, S. Goyal, D. Iyer, M. Luengo, J. Pascual, and Shani, S. (2007). An integrated water, sanitation and health strategy for the municipality of Ruiru, Kenya. School of International and Public Affairs (SIPA), Columbia University, New York, NY.

Choldin, H. M. (1978). Urban density and pathology. *Annual Reviews, Sociology*, Vol **4**, pp 91-113.

Government of Kenya. (2006). Environmental Management and Co-ordination (Water Quality) Regulation. Kenya Gazette supplement, No 68 (Legislative supplement No. 36).

Grau, H. R. and T. and Alde, M. (2007). Are Rural–Urban Migration and Sustainable Development Compatible in Mountain Systems? *Mountain Research and Development,* Vol **27**(2), pp 119–123.

Mohammed, S. M. (2002). A review of water quality and pollution studies in Tanzania. *Ambio*., Vol **31** (7-8), pp 617-620.

Nelson, K. L. and Murray, A. (2008). Sanitation for unserved Populations: Technologies, Implementation Challenges, and Opportunities. Annual Reviews, *Environmental Resources*, Vol **33**, pp 119-151.

Scheren, P. A. G. M., H. A. Zanting and. Lemmens, A. M. C (2000). Estimation of water pollution sources in Lake Victoria, East Africa: Application and Elaboration of the rapid assessment methodology. *J. Environmental Management,* **58**, pp 235-248.

Sobel, J., Gomes, T. A. T., Ramos, R. T. S., Hoekstra, M., Rodrigue, D., Rassi, V. and Griffin, P. M. (2004). Pathogen-Specific Risk Factors and Protective Factors for Acute Diarrheal Illness in Children Aged 12–59 Months in Sao Paulo, Brazil. *Clinical Infectious Diseases,* **38**, pp 1545-1551.

ASSESSMENT OF THE WATER QUALITY STATUS OF SASUMUA WATERSHED, KENYA

J. K. Mwangi[1], G. T. Thiong'o[2] and J. M. Gathenya[3]
[1]Department of Civil Construction and Environmental Engineering, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[2]Department of Chemistry, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[3] Department of Biomechanical and Environmental Engineering, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: Joymwa86@yahoo.com

Abstract
This study focuses on Sasumua watershed (107km^2) of the Upper Tana basin and source to 20% of Nairobi's water supply where intensification of human activity has resulted in increased pollutional load to Sasumua reservoir with implications on water treatment costs for Nairobi Water and Sewerage Company (CNWSC). The objective of the study was to determine the physico-chemical and bacteriological characteristics of the water entering Sasumua reservoir and to assess the relative importance of the various sources of contamination. Water samples were collected at distinct land use boundaries, at reservoir entry/exit points, and at the surface of the reservoir during both dry and wet seasons. These were analysed to determine total suspended solids, total dissolved solids, turbidity, dissolved oxygen, faecal coliforms, nutrients, heavy metals and pesticides. Analysis was done as per the standard method of analysis and evaluation based on World Health Organisation (WHO) standards. For both dry and wet seasons most parameters were within WHO standards except Ming'utio River which showed exaggerated levels of potassium, iron, lead, manganese, pH and turbidity. For the wet season both turbidity and pH values were above WHO standards for most samples analysed. No pesticides were detected but samples showed signs of contamination with human waste indicating unsuitability for domestic use without treatment. Turbidity and pH were the major issues of concern because of their bearing on water treatment costs. The study contributes towards understanding the water quality status of the contributing rivers and reservoir and can be used by planners to devise ecologically-sound watershed management plans, or by policy makers to evaluate alternative land management options that can abate pollution of water bodies.

Key words: Pollutants, Sasumua, water quality, watershed, WHO

1.0 Introduction

Rivers are the most important sources of fresh water for man. The social, economic and political developments have largely been related to the availability and distribution of fresh waters contained in riverine systems. Water quality problems have intensified over time in response to increased growth and concentration of populations and industrial centres. Polluted water is an important vehicle for the spread of water related diseases with 1.8 million people, mostly children dying every year especially in developing countries (WHO, 2004). Outbreaks of waterborne disease continue to occur in both developed and developing countries, leading to loss of life, disease and economic burden for individuals and communities. Improvements in water quality and personal hygiene can therefore be expected to deliver substantial health gains in the population.

Economic and demographic growth in agricultural watersheds often leads to intensive land use and increased generation of point and non-point source pollutants. These pollutants, which include pathogens, nutrients, toxic contaminants, and sediments are then transported by runoff to water bodies causing serious environmental effects (Johnes and Burt, 1991). Many types of fish and other aquatic animals cannot survive in environments with high amounts of oxidizable organic pollutants that can cause levels of dissolved oxygen to drop below 5 ppm (Chapman, 1992). When this occurs, aquatic organisms are killed in large numbers leading to significant disruptions in the food chain. Organic or inorganic materials enter waterways in many different forms from terrestrial ecosystem or/and from the atmosphere. The major sources of terrestrial water pollution can be classified as municipal, industrial, and agricultural. Municipal water pollutants consist of wastewater from homes and commercial establishments. Agricultural land including commercial livestock and poultry farming is the source of many organic and inorganic pollutants in surface and ground waters (Chapman, 1992). These contaminants include both sediment from eroded croplands and compounds of phosphorus and nitrogen that partly originate from animal wastes and commercial fertilizers. Animal wastes are high in oxygen demanding, nitrogen and phosphorus, and they often harbour pathogenic organisms. High nutrient loadings may lead to eutrophication of water bodies. Intensive agricultural practices have the potential to introduce heavy loads of sediment, nutrients, and faecal contamination into surface waters with resultant water quality problems.

These pollutants reach streams through surface, sub-surface and ground water flow depending on the type of pollutant. Surface runoff is the major pathway for organic and inorganic sediments and particulate-bound nutrients such as phosphorus (Chittleborough *et al.*, 1994; Lal, 1990). Sediments may also be important for the transport of organic forms of nitrogen, particularly when surface runoff is the dominant storm water pathway (Schuman *et al.*, 1973; Hubbard *et al.*, 1982). Surface runoff may also be the major transport mechanism for soluble pollutants, especially after applications of agrochemicals or livestock waste (Neilsen *et al.*, 1982; Roberts, 1987; Smith, 1989; Bengtson *et al.,* 1988, 1990; Schlefield and Stone, 1991). Most water pollutants are eventually carried by rivers into oceans, reservoirs and other water bodies.

Sediments and nutrients in water bodies may also originate from roads, bank erosion, re-suspension, production processes (for nitrogen), and fluvial erosion. In the case of streams, high flow and change in the direction of the current are responsible for bank erosion, re-suspension and fluvial erosion. Birot (1968), Tricart (1972) and Louis (1964) observed that most of the humid tropical rivers do not erode vertically into the material below them. Also on a global scale several researchers (NEDECO, 1959; Webb and Walling, 1985) reported average contribution of bedload ranging between 5 to 10 %. This range of values is conveniently considered as insignificant, thus most estimates of net erosion rely wholly on suspended loads.

Atmospheric pollutants (wet or dry) are transferred to water bodies by precipitation. For several Western countries, about 20-40% of the total phosphorus load is deposited by rain (Sharpley *et al.*,

1994). The relative contribution of atmospheric input compared to the terrestrial sources depend on pollutant type, areal coverage of the water body, the size of the terrestrial ecosystem, connectivity of its watersheds, and the type of activity both at local and regional scales. Apart from natural factors such as precipitation, evaporation, geology, soils influencing water quality, human activities such as domestic and agricultural practices impact negatively on river water quality. It is therefore important to carry out regular water quality assessments for sustainable management of water bodies and watersheds.

Kenya's water resources, like other developing countries, have been under increasing threat of pollution in recent years due to rapid demographic changes, which have coincided with the establishment of human settlement lacking appropriate sanitary infrastructure (Verma and Srivastava, 1990). Sasumua watershed is crucial for the production of ecosystem services, not only for the local population but also for Nairobi City dwellers because Nairobi derives 20% of its water needs from the watershed. Land use changes, driven by agricultural production have contributed to degradation of watershed functioning. This has resulted not only in degradation of hydrological functioning of the regime, but also in lowering of soil productivity which has impacted negatively on the livelihood of the rural communities. Because of increased population, farming has intensified in order to produce enough food for the population with farmers using more inorganic fertilizers, pesticides, and herbicides. Other than food production, however agricultural watersheds are also expected to provide ecosystem services such as clean and regular flow of water to people living downstream. With intensification of agriculture, it is expected that water quality and quantity will be affected with serious ramification on the livelihoods of both local communities and NWSC. Ensuring proper hydrological functioning of the watershed is therefore of critical importance to the future water supply of Nairobi.

Sasumua River with its tributaries runs through farmlands and rural communities before entering Sasumua reservoir the major source of water for Nairobi. Although NWSC regularly treats its water before transmission to Nairobi, no water quality studies have been done on the rivers before the water enters the reservoir to determine the relative importance of various sources of contamination and their contribution to the overall water quality. Understanding the nature of sources of contamination and how these contaminants enter the water supply is critical for assuring water safety. The study aims at determining the water quality status of Sasumua watershed and to provide physico-chemical and bacteriological characteristics of the water and therefore contribute to the formulation of ecologically-sound watershed management plans for abating pollution of Sasumua reservoir and its contributing rivers.

2.0 Materials and Methods

2.1 Study Area

Sasumua watershed lies between longitudes 36.58°E and 36.68°E and latitudes 0.65°S and 0.78°S with an altitudinal range of 2200 m amsl to 3850 m amsl. Apart from Njabini Township and other market centres where there are commercial activities; farming is the main socio-economic activity in the watershed with potatoes, cabbages, kales, garden peas and carrots being grown for the Nairobi urban market. The ready market for these products has led to increased use of inorganic fertilizers, pesticides and fungicides making water pollution from these agro-chemicals a challenge in the watershed. The steep slopes and heavy rainfall in the watershed make much of its area vulnerable to degradation- a problem exacerbated by population pressures. Large scale immigration to the area in recent years combined with intrinsic growth has resulted in a population explosion in the area. As the population has increased, so has the demand for key natural resources, such as land, water and energy, heightening risks of ecosystem degradation. These anthropogenic processes have led to significant decline in water quality in Sasumua watershed during the last four decades (Mireri, 2009). Climate in the watershed varies with altitude, with rainfall increasing while temperatures decreases

as elevation increases. The mean annual rainfall in the watershed ranges from 1000-1600 mm, with an increasing gradient from South-West to North-East. The distribution of rainfall is binomial with long rains occurring from March to May and short rains occurring from October to December, (Gathenya *et al.,* 2009) with sufficient amounts in most of the other months. The mean monthly temperature is 11.54°C while annual potential evaporation ranges from 1180mm to 1322mm (Woodhead, 1968).

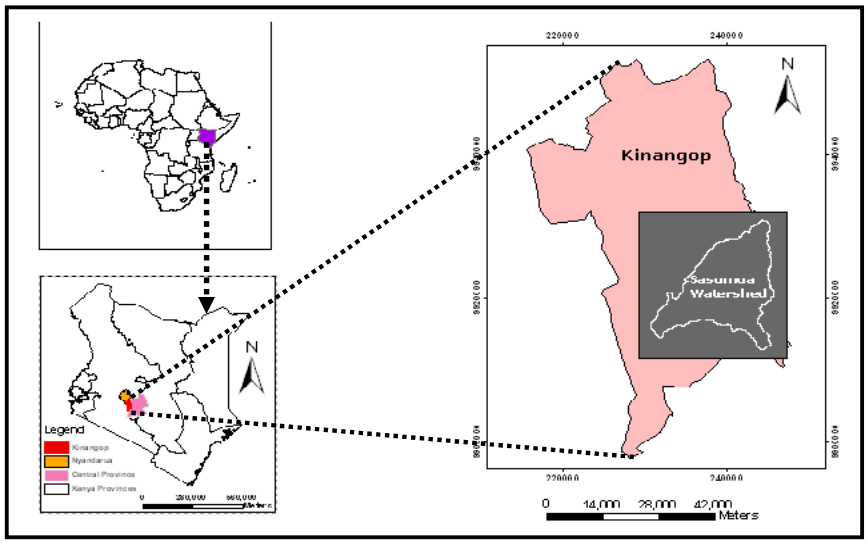


Figure 1: Geographical Location of the study area

The total population of the watershed is about 19,000 (2009 census) in two divisions of Nyakio and Njabini.

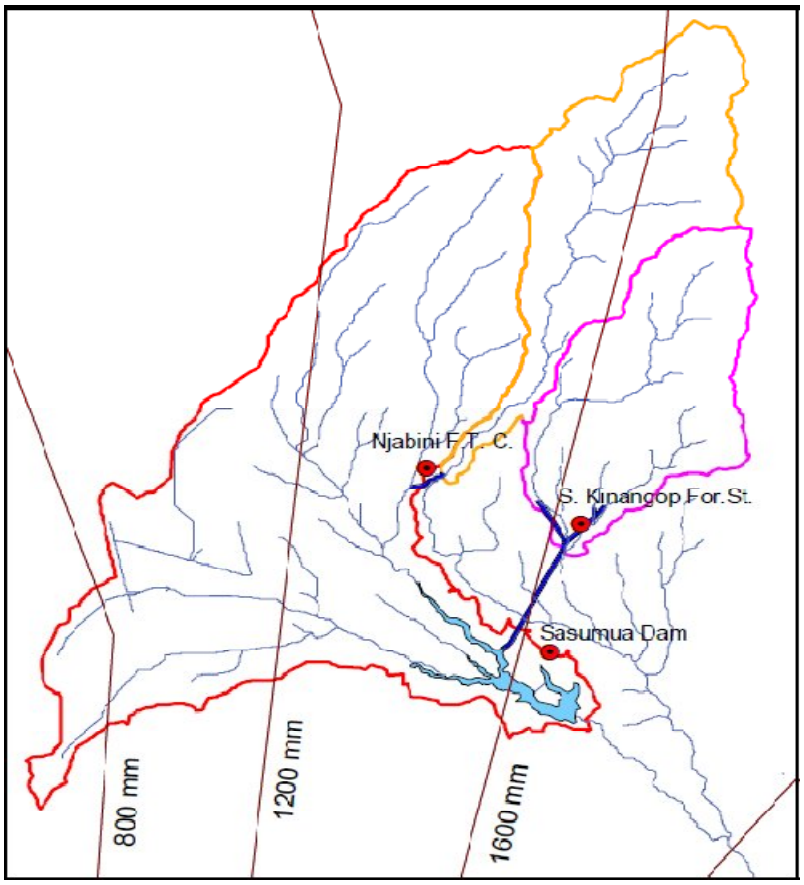


Figure 2: Mean annual rainfall distribution and rainfall stations

2.2 Sampling

Surface water samples for physico-chemical analysis were collected midstream at a depth of about 20cm directly into clean 500ml plastic bottles. Temperature and pH were measured *insitu*, using a temperature probe and a portable pH meter, respectively. Electrical conductivity (EC) and total dissolved solids (TDS) were determined on site using total dissolved solid (TDS) and conductivity meter Jenway model 4076. Dissolved oxygen (wet season only) was determined on-site using multi-meter electrochemical analyzer Jenway, model 3405. Wet season turbidity was measured on site using TR-3Z KRK Turbidimeter meter model 1042 while dry season turbidity was measured in the laboratory. Samples for bacteriological analysis were collected at Ming'utio and Sasumua Rivers and at Kwa-Haraka town into sterilized 1-litre plastic bottles while ensuring no air bubbles were present, stored in an icebox at 4°C and transported to the laboratory for analysis within the stipulated time of 6 hours. Microbiological analysis of these samples was carried out using the standard methods (APHA, 1998) and the experiments performed in triplicates. The plates were incubated at 35^{o}C for 24 hrs and bacteria counts (both feacal and total coli forms) in the water samples enumerated using the membrane filtration technique. The choice of sampling points was based on entry points of major rivers into the reservoir, exit of water from the reservoir and areas where distinct land use changes occurred (Figure 3). It was carried out both during the dry and wet seasons. Twelve sampling points were selected for both the dry and wet seasons. The geographical location of these points was determined using a geographical positioning system (GPS). The samples were collected in 500ml pre-washed and labeled polypropylene bottles which were thoroughly washed and rinsed with tap and distilled waters. They were again rinsed with river water before actual sample collection and filled to the top to eliminate air bubbles and then firmly corked. Samples for trace metals analysis were acidified to PH <2 by addition of nitric acid while those meant for anion analysis were collected in

the same way but without the need for acidification. Five sampling points were selected for pesticide analysis. Temperature, pH, electrical conductivity, and total dissolved solids were determined on site using total dissolved solids (TDS) and Electrical conductivity meter Jenway model 4076.

Figure 4: Sampling for water quality at Sasumua reservoir

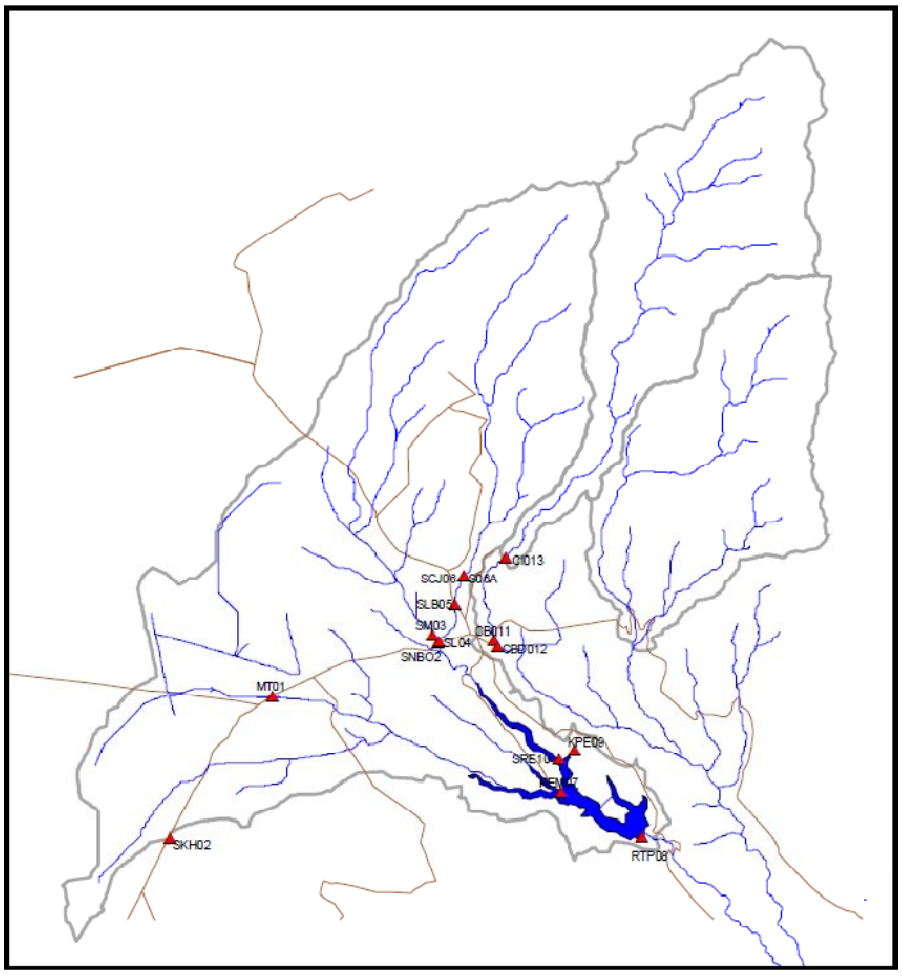


Figure 3: Water quality sampling points in Sasumua watershed

Table 1: Sampling points within Sasumua watershed

Code	Description	UTMX	UTMY
MT 01	Ming'utio River at the bridge	235063	9918772
SNB 02	Sasumua river at the Njabini-Nairobi Bridge	238074	9919782
SM 03	Main Sasumua River	237983	9919930
SL 04	Little Sasumua River and Chania tunnel junction	238101	9919818
SLB 05	Little Sasumua + Tunnel at Bridge to Engineer	238394	9920508
SCJ 06	Little Sasumua + Tunnel at junction	238557	9921024
REM 07	Reservoir at entry of Ming'utio river	240318	9916954
RTP 08	Reservoir at tower point	241812	9916122
KEP 09	Entry of Kiburu pipe at reservoir	240570	9917772
SRE 10	Reservoir entry of Sasumua River	240282	9917588
CI 013	Chania Intake	239321	9921368
SKH 02	Kwa-Haraka township	233185	9916113

2.2.1 Laboratory Analysis

The methods outlined in the standard Methods for the Examination of Water and Waste water (APHA, 1998) were followed for the analysis of all physico-chemical parameters. Total suspended solids (TSS) were measured gravimetrically after drying in an oven to a constant weight at 105°C. Total and faecal coliforms were determined by membrane filtration method using M-Endo-Agar Les at 37°C and on MFC Agar at 44°C, respectively. Sodium and potassium were analysed using the flame emission photometry; calcium and magnesium by EDTA titration; and chloride by argentometric titration. Analysis of Mg, Ca, and heavy metals (Fe, Mn, Cu, Zn, Pb and Cd) were done using atomic absorption spectrophotometer (AAS) Buck Scientific – 210 VGP (air – acetylene flame). Analysis of sodium (Na) and potassium (K) were done using Flame emission spectrophotometer using Corning 400 ; Na^+ at 590nm and for K^+ at 770nm. Analysis of organochlorines and organophosphates was done by Gas Chromatography GC-ECD/NFD at KEPHIS analytical laboratory (A SANAS Accredited Testing Laboratory No.T0209.

Standard stock solutions for each metal analyte were prepared using respective analar grade reagents for each analyte which was dissolved in distilled water and from which dilutions calibration curves were prepared.

Each of the analyte (NO_2^-, NO_3^-, PO_4^{2-}, and SO_4^{2-}) was analyzed using calorimetric technique. Analytes (NO_2^- , PO_4^{2-}, and SO_4^{2-}) were analyzed using visible spectrophotometer (Pharmacia Biotech – model Nova spec II) while NO_3^- was analyzed using Shimadzu 1700 UV-visible Spectrophotometer (Vogel, 1989). All reagents used were of analar grade while distilled water was used for preparation of standards.

3.0 Results and Discussions

The results of the analysis are presented in tables and those above WHO standards are shown in bold. The mean pH for most samples was neutral (7.10) which is the range associated with most natural waters (6.0 to 8.5), stipulated for drinking and domestic purposes (Chapman, 1992). The conductivity of the water at sampling points ranged between (0-180). The turbidity of the water ranged from 2.0 to 142.0 during the wet period which is the most critical period and which was expected considering most runoff occurs during the rainy season and which carries alot of silt. Low turbidity facilitates water purification process like flocculation and filtration resulting in reduced treatment costs. Dissolved oxygen (DO) levels varied from 6.3 to 11.90 during wet season and this could be attributed to availability of limited organic waste in the waters. Measurement of DO gives a rough indication of the quality of the water (DFID, 1999) as most polluted waters have DO below 5mg/l making them unsuitable for existence of aquatic life. Nitrate and Nitrite levels were within levels recommended by WHO. High concentrations of these ions pose health risks particularly in pregnant women and bottle-fed infants (Kelter *et al.,* 1997).

Ming'utio sampling point (MT 01) showed high phosphate, iron, lead and manganese concentrations and because of the sensitivity of high concentration of lead, all sampling points that showed traces of lead and cadmium were re-tested at the Institute of Nuclear Science and Technology University of Nairobi and at KEPHIS analytical laboratory. Although in both cases the levels were below WHO standards there was still cause for concern as these elements are not normally removed by conventional water treatment methods. Nutrient levels were low during the dry season but increased significantly during the wet season. The bacteriological quality of water sampled was poor rendering it unsafe for domestic purposes without treatment. The poor bacteriological quality may be due to contact with human or animal waste.

Although most of the physico-chemical parameters for water quality were within the acceptable guideline limits of the World Health Organization (WHO) for potable water, there is still cause for

concern especially with regard to some elements which are not removed during normal treatment and possible sources of these elements should be indentified and preventive measures taken to prevent their discharge into rivers.

Table 2: Pesticide results for wet season

Sampling Site	*Pesticide screening*	*Concentration (mg/l)*
SNB 02	Organophosphates Organochlorines	< Limit of detection <Limit of detection
MT 01	Organophosphates Organochlorines	<Limit of detection <Limit of detection
CB 11	Organophosphates Organochlorines	<Limit of detection <Limit of detection
SL 04	Organophosphates Organochlorines	<Limit of detection <limit of detection

Table 3: Coli form test results on water samples

Sampling site	*eColi MPN index per 100ml*	*WHO standard*
MT 01	>1100	0
SKH 02	>1100	0
SNB 02	43	0

Table 4: Nutrient concentration in Sasumua reservoir and contributing rivers (Wet season mg/l)

Sample site	NO_2^-	NO_3^-	SO_4^{2-}	PO_4^{2-}	Na^+	K^+	Mg^+	Ca^{2+}	Cu^{2+}	Fe^+	Pb^{2+}	Mn^{2+}	Cd^{2+}
MT01	0.13	59.28	53.52	0.74	16.85	13.81	1.10	2.21	0.00	1.84	0.06	0.87	0.00
SNB02	0.01	35.88	71.83	0.32	2.66	1.84	0.87	2.61	0.01	0.20	0.16	0.02	0.00
SM03	0.04	88.92	14.79	0.96	10.64	6.44	1.24	1.81	0.00	3.26	0.02	0.98	0.02
SL04	0.02	62.40	16.20	0.21	3.55	1.84	0.85	2.31	0.01	0.28	0.01	0.04	0.00
SLB05	0.02	65.52	50.70	0.53	79.84	234.70	0.84	2.71	0.01	0.13	0.10	0.05	0.00
SCJ06	0.02	17.16	14.79	0.43	3.55	1.84	0.85	2.24	0.00	0.17	0.01	0.04	0.00
REM07	0.00	0.00	8.45	0.32	3.55	1.84	1.04	2.98	0.01	0.18	0.00	0.05	0.00
RTP08	0.02	37.44	12.68	0.43	4.44	1.84	1.22	2.44	0.01	0.08	0.07	0.02	0.00
KEP09	0.05	62.40	13.38	0.74	3.55	1.84	1.06	1.50	0.01	0.23	0.00	0.01	0.01
SRE10	0.03	49.92	9.86	0.74	3.55	1.84	1.00	2.25	0.02	0.23	0.08	0.04	0.00
CI013	0.02	46.80	11.27	0.32	3.55	1.84	0.94	2.54	0.02	0.11	0.00	0.02	0.00

SKH01	0.00	0.00	67.61	0.74	13.31	8.28	0.38	1.21	0.02	0.75	0.13	0.5	0.00
SKH02	0.05	477.38	10.56	0.63	67.42	59.83	1.97	51.23	0.00	0.23	0.01	0.23	0.00
WHO	350	250	0.2-3	5	200	30	50	250	1-2	0.3	0.01	0.4	0.003

Table 5: Nutrient concentration in Sasumua reservoir and rivers flowing into it (Dry season mg/l)

Sample site	SO_4^{2-}	NO_2^-	NO_3^-	PO_4^{2-}	Na^+	K^+	Mg^+	Ca^{2+}	Cu^{2+}	Fe^+	Pb^{2+}	Mn^{2+}	Cd^{2+}
MT01	56.50	0.50	8.90	9.69	20.62	21.08	1.75	1.89	0.31	18.46	0.23	4.08	0.00
SNB02	7.21	0.78	7.52	0.68	4.48	4.58	1.54	2.70	0.00	0.49	0.07	0.23	0.00
SM03	71.50	0.30	7.85	0.25	11.65	11.92	1.13	1.83	0.00	2.87	0.00	2.51	0.01
SL04	28.64	0.17	7.14	0.39	4.48	4.58	1.63	2.15	0.00	1.19	0.01	0.43	0.00
SLB05	76.50	0.70	7.55	1.52	3.59	3.67	1.51	3.17	0.00	0.35	0.02	0.11	0.00
SCJ06	31.50	0.17	7.69	0.25	4.48	4.58	1.35	2.51	0.01	0.14	0.01	0.03	0.00
REM07	20.07	0.04	7.93	1.52	5.38	5.50	1.25	1.96	0.01	0.72	0.01	0.21	0.01
RTP08	55.07	0.17	7.55	0.25	4.48	4.58	0.78	0.96	0.00	0.47	0.00	0.00	0.00
KEP09	22.93	0.58	6.88	0.25	4.48	4.58	1.48	1.53	0.02	0.66	0.04	0.10	0.00
SRE10	21.50	0.34	7.54	0.68	4.48	4.58	1.48	2.31	0.00	0.18	0.18	0.17	0.01
CI013	60.79	0.05	7.16	0.39	3.59	3.67	1.09	2.40	0.00	0.17	0.01	0.01	0.00
WHO	0.2-3.0	350	250	5	200	30	50	250	1-2	0.3	0.01	0.4	0.003

Table 6: Physical characteristics of Sasumua reservoir water and rivers flowing into it (Wet season)

Sample site	Conductivity (EC mS/cm)	Total dissolved solids (TDS mg/l)	Temperature (°C)	pH	Dissolved Oxygen mg/l)	Turbidity (NTU)
MT01	0.07	51.00	19.00	6.90	8.60	22.00
SNB02	0.03	21.00	12.00	8.00	10.40	7.00
SM03	0.69	54.00	16.80	7.42	7.90	11.00
SL04	0.03	21.00	12.80	7.90	8.60	22.00
SLB05	0.53	28.00	13.40	6.21	8.10	27.00
SCJ06	0.30	25.0	13.50	6.17	7.80	5.00
REM07	0.04	28.00	19.10	8.06	10.80	5.00
RTP08	0.03	28.00	18.00	7.74	7.80	2.00
KEP09	0.37	25.00	13.20	7.63	9.20	30.00
SRE10	0.35	27.00	15.80	8.60	10.80	25.00

CI013	0.02	21.00	13.20	6.39	6.30	1.00
SKH01	0.08	52.70	15.50	5.50	11.90	142.00
SKH02	0.85	62.40	18.00	6.94	9.00	86.00
WHO	500-5000	1000		6.5-8.00		5

Table 7: Physical characteristics of Sasumua reservoir and contributing rivers (Dry season)

Sample site	Conductivity (EC mS/cm)	Total dissolved solids (TDS mg/l)	Temperature (°C)	pH
MT01	180	123	16.00	6.1
SNB02	0	0	12.80	6.2
SM03	70	47	18.20	5.9
SL04	40	30	13.00	6.7
SLB05	40	30	12.80	6.8
SCJ06	40	30	13.50	7.1
REM07	40	27	19.20	8.20
RTP08	30	25	17.60	7.9
KEP09	40	28	13.10	7.6
SRE10	50	3	15.20	7.6
CI013	30	23	13.10	7.8
WHO	500-5000	1000		6.5-8.00

4.0 Conclusions and Recommendations

The results indicated that most of the physico-chemical water quality parameters were within the WHO and KEBS limits for drinking water and the water is therefore suitable for domestic purposes. In contrast however, the bacteriological quality of the water as indicated by the total and faecal coliform counts exceeded the standard (0cfu per 100ml) for portable water. In general the bacteriological quality of the water was unacceptable as it may pose risk to consumers without treatment. The poor quality showed possible contamination with human or animal waste. Inadequate physical infrastructure, especially heavy reliance on pit latrines and weak solid waste management mechanisms. Lack of functioning solid and liquid waste management system in the rapidly growing urban centre represents an important source of pollutants, which may find its way into water resources.

Conductivity and Total dissolved solids (TDS) and other major ions varied from wet to dry season with elevated levels in the wet season. However, nutrient levels were generally low during the study period although they were higher during the wet season. However, despite these low levels care should be exercised by farmers in the application of inorganic fertilizers in order to avoid eutrophication of rivers or even the reservoir. For the sampled points, no organophosphates or organochlorines were detected.

Water resource management is an integral aspect of the preventive management of drinking-water quality. Prevention of microbial and chemical contamination of source water is the first barrier against drinking-water contamination of public health concern. Water resource management and potentially polluting human activity in the catchment will normally influence water quality downstream and this will impact on water treatment steps required to ensure safe water. The influence of land use on water quality should be assessed as part of water resource management which is normally the responsibility of catchment management bodies which implement national policies on integrated water resource management.

From Total Suspended Solids results it is clear that sediments are a major source of pollution and therefore further analysis is recommended to identify the major sources and possible measures to mitigate this possibly using a hydrological model. There is need also to create awareness about the risks associated with poor watershed management and the benefits of effective watershed management among the rural communities. For the urban settlements and town centres, there is need to put in place the necessary infrastructure and systems for solid and liquid waste management.

References

APHA, (1998): Standard method for the Examination of Water and Wastewater, 2nd Edition APHA, Washington D.C.

Bengtson, R. L., Carter, C. E., Morris, H. F. and S. A. Bartkiewicz (1988). The influence of subsurface drainage practices on nitrogen and phosphorus losses in a warm, humid climate. *Trans. ASAE*, **31**, pp 729-733.

Birot, P. (1968). The cycle of erosion in different climates. London, Bats ford. pp 876-877

Burt, T. P., Arkell, B. P., Trudgill, S. T. and Willing, D. E. (1988). Stream nitrate levels in a small catchment in southwest England over a period of 15 years (1970-1985). *Hydrological Processes*, **2**, pp 265-285.

Chapman D. (1992). Water quality Assessments; A guide to the use of biodata, sediments and water in Environmental Monitoring. University Press, Cambridge, 585 pp.

Chittleborough, D. J., K. R. J. Smetten, and Kirkby, C. A. (1994). Clay, Phosphate and water movement through a texture contrast soil. Final report to the land and water resources research and Development Corporation of Australia for project UAD1. Clarendon Press – Oxford. p.79.

DFID (1999). A simple methodology for water quality Monitoring. (G.R. Pearcce, Chaundry and S. Ghulum, editors). Department for International Development, Wallingford.

Franson, M., (1998). Standard methods for the examination of water and waste water. American Public Health Association.

Gathenya, J. M., Thiong'o G. T. and Mwangi, J. K. (2009). Hydrological modelling and water Quality Assessment of Sasumua watershed.

Hubbard, R. K., Erikson, A. E., Ellis, D. G. and Wolcott, A. R. (1982). Movement of diffuse source pollutants in small agricultural watersheds of the Great Lake Basin. *J. Environ.* Qu*al.*,**11**, pp117-123.

Johnes, P. J. and Burt, T. P. (1991). Water quality trends in the Windrush catchment: nitrogen specification and sediment interactions. In: N.E. Peters and D.E. Walling (Eds). Sediment and Stream Water Quality in a Changing Environment: Trends and Explanation. IAHS Publication N° 203, IAHS Press, Wallingford, UK, pp. 349-357.

Kelter P. B., Grudma,n J., Hage, D. S. and Carr, J. D. (1997). A discussion of water pollution in the US and Mexico with High School laboratory Activities for analysis of lead, anthrazine and nitrate. *Chem. Educ*. **74** (12), pp 1413-1418

Lal, R and Stewart, B.A. (1990. Soil degradation A global threat In: Lal, R and Stewart, B.A. (Eds). Advances in Soil Science, pp 13-17.

Mireri, C., (2009). Preliminary Environmental Audit report of Sasumua watershed, Kenya. A Consultancy report for the World Agroforesty Centre (ICRAF), Nairobi Kenya.

NEDECCO (1959). River studies-Niger and Bemue. Amsterdam. North-Holland.

Neilsen, G. H., Culley, J. L. B. and Cameron, D. R. (1982). Agriculture of water quality in the Canadian Great Lakes Basin: IV. Nitrogen. *J. Environ.* Qu*al.,* **11**, pp 493-497.

Roberts, G. (1987). Nitrogen inputs and outputs in a small agricultural catchment in the eastern part of the United Kingdom. *Soil Use management,* **3**, pp 148-154.

Sharpley, A. N., Chapara, S. C., Wedepohl, R., Sims, J. T., Daniel, T. C. and Reddy, K.R. (1994). Managing agricultural phosphorus for protection of surface waters: issues and options. *J. Environ. Qual*., **23**, pp 437-451.

Scholefield, D. and Stone, A. C. (1991). Livestock wastes pollute surface waters. In: Research for a cleaner Environment. Silsoe Research Institute and AFRC Institute of Grassland and Environmental Research Joint publication. Silsoe Research Institute, UK, p. 15.

Schuman, G. E, R. G. Spomer, and Piest, R. F. (1973a). Phosphorus losses from four agricultural watersheds on Missouri Valley loess. Soil Sci. *Soc. Am. Proc.,* **37**, pp 424-427.

Schuman, G. E, R. E. Burwell, R. F. Piest, and Spomer, R. G. (1973b). Nitrogen Losses in surface runoff from agricultural watersheds on Missouri Valley loess. *J. Environ. Qual*., **2**, pp 299-302.

Smith, C. M. (1989). Riparian pasture retirement effects on sediment, phosphorus and nitrogen in channelized surface runoff from pastures. N.Z.J. Mar. *Freshwater Res.,* **23**, pp 139-146.

Tricart, J. (1972). The landforms of the humid tropics, forest and savannas. London. Longman.

Verma, B. L. and Srivastava, R. N. (1990). Measurement of personal Cost of illness due to some Major Water-related issues in an Indian Rural Population. *Int. J. Epidemiol*., **19**, pp 169-176.

Webb, B. W. and Walling, D. E. (1985). Nitrate behaviour in stream flow from grassland catchment in Devon U.K. *Water Res.,* **19**, pp 1005-1016.

WHO (2004): *www.who.int/water_sanitation-ealth/publications/facts2004/en/index.html*

IMPACTS OF BEST MANAGEMENT PRACTICES (BMPS) ON WATER QUANTITY AND QUALITY OF MALEWA BASIN

L. P. Ogweno[1], J. M. Gathenya[2], and P. G. Home[3]
[1] Kenya Industrial Research and Development Institute, Nairobi, Kenya
[2,3]Department of Biomechanical and Environmental Engineering, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: ogwenop@gmail.com

Abstract
This paper evaluated the impacts of best management practices (BMPs) on water quality and quantity of Malewa selected subbasins. Soil and Water Assessment Tool model was used in evaluating the effects of implementing BMPs. The model was calibrated and validated before doing BMPs scenarios of changing filter widths from 0 to 5m to 10m and altering the USLE-P factor from default value of (no conservation measure) to 0.65 and 0.1 respectively. The two scenarios were done independently. From the results, it was observed that filter strips were having varying effectiveness at reducing overland flow, sedimentation, and removing nutrients. The hydrologic benefit of riparian buffers increases with width. Considerable reductions in sediment concentrations occur when 5m wide filter strips are simulated. However, increasing the filter strips by an additional 5m (total 10 m) does not produce the same level of reductions as was observed for the 0 to 5m condition. This suggests that benefits from implementing filter strips will taper off for further increases in filter width. Reductions were slightly higher for sub-with moderate slope gradient compared to sub-basins with steep slopes. Also headwater sub-basins recorded greater reductions in sediment exports (e.g., 17, 13) compared to sub-basins located downstream (e.g., 23 and 19). Clearly greater improvements in water quality could be achieved by targeting headwater sub-basins. The impact of simulating filter strips on the sediment load at the main watershed outlet was also determined. The 5m filter scenarios produces a 17% reduction in sediment load, whereas doubling the filter widths only decreases the load by an additional 5%.

1.0 Introduction

Best Management Practices (BMPs) are recommended methods, structures, and practices designed to prevent or reduce water pollution while maintaining economic returns. The BMPs concept deals specifically with nonpoint source pollution, such as runoff from agricultural fields. Implicit within the BMPs concept is a voluntary, site-specific approach to water quality problems. Many of these methods are already standard practices, known to be both environmentally and economically sustainable.

Best Management Practices prevent pollution from agricultural operations. Plant nutrients, bacteria, sediment and agricultural chemicals can be controlled so that pollution of surface and ground water does not occur and limit the use for drinking, aquatic life and recreation. Odor, vectors, and other nuisances can also be minimized by adequate BMP's. Implementation of Best Management Practices (BMPs) is a conventional approach for controlling nonpoint sources of sediments and nutrients. However, implementation of BMPs is rarely followed by a good long-term data monitoring program in place to study how effective they have been in meeting their original goals. Long-term data on flow and water quality within watersheds, before and after placement of BMPs, is not generally available. Therefore, evaluation of BMPs (especially new ones that have had little or no history of use) must be necessarily conducted through watershed models.

The availability and quality of freshwater supplies for human and ecological needs are critical factors influencing the health and livelihoods of all people in a nation. Continued growth in human population and water use, continued degradation of water supplies by contamination, and greater recognition of the legitimate needs for freshwater in order to support critical ecosystem functions will lead to increasing scarcity and conflict over freshwater supplies in coming years.

Effective hydrological modeling of watersheds is an essential tool in the management of land degradation and its off-site impacts, such as those associated with salinity and nutrient problems. Various methods have been used in the past to model processes and responses in catchment hydrology. Catchment hydrology models can be considered crudely as either, physical, conceptual or empirical. Each of these modeling approaches suffers from certain inadequacies (Wheater *et al*., 1993.)

The effects of land use on water resources vary according to local conditions. The assessment is difficult due to large delays between cause and effect and the interference between anthropic and natural impacts caused by, e.g., climatic changes. These limitations make it difficult to draw general conclusions about the relations between land and water use in watersheds. However, some experiences show that land management impacts on watershed hydrology and sedimentation are observed more clearly in small-scale watersheds of about tens of square kilometers. Some land management effects on water quality can be observed also at larger scales. In recent years there has been an increasing trend to predict hydrologic changes brought about by land cover transformations in the tropics by robust models employing data obtained during relatively short but intensive measuring periods (Shuttleworth, 1990 and Institute of Hydrology, 1990).

Effective hydrological modeling of watersheds is an essential tool in the management of land degradation and its off-site impacts, such as those associated with salinity and nutrient problems. Various methods have been used in the past to model processes and responses in catchment hydrology. Catchment hydrology models can be considered crudely as either, physical, conceptual or empirical. Each of these modeling approaches suffers from certain inadequacies

2.0 Overview of the Study Area

Malewa basin lies between the two flanks of the Eastern or Gregory Rift Valley, with the Aberdares Mountains and Kinangop plateau on the east and the Mau Escarpment on the west. The Malewa basin is situated in the central Rift Valley, Naivasha District in Kenya about 100 km northwest from Nairobi (Figure 1). Its geographical position lies between 36°15'E-36°30'E longitude and 00°40'S-00°53'S latitude. The altitude ranges from 1900-3980m.a.m.s.l.

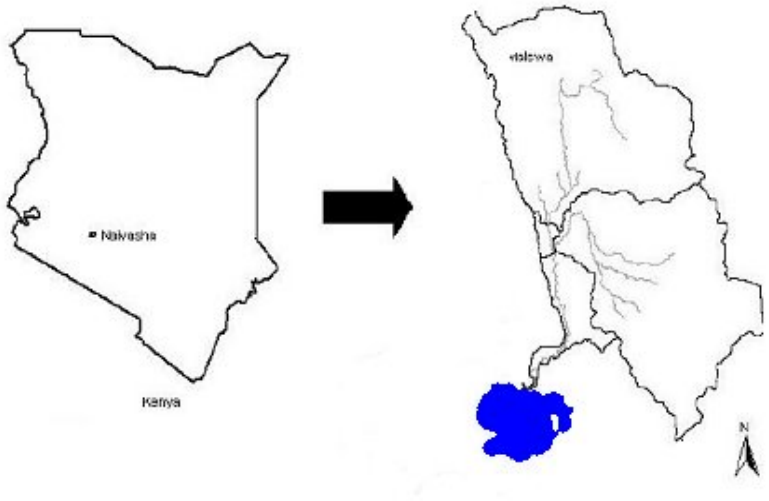


Figure 1: Map of the study area (Lake Naivasha-Malewa basin)

2.1 Climate

The Malewa basin belongs to a semi-arid type of climate. The rainfall distribution has a bimodal character (Figure 2). The long term spatial distribution of rain varies from 600mm at Naivasha town to 1700mm at the slopes of the Nyandarua Mountains the Kinangop plateau experiences a yearly rainfall from 1000mm and 1300mm (Becht and Higgins 2003). Longer rainy season occurs in March-May and short rainy seasons occur in October-November (Kamoni, 1988). February, July and December are the driest months of the year. The lowest temperatures are experienced in July, while the highest temperatures occur in March. The potential evaporation is about twice the annual rainfall in the semi arid area while in the upper basin humid areas, rainfall exceeds potential evaporation in most parts of the year (Farah, 2001). The annual temperature range is approximately from 8^0C to 30^0C.

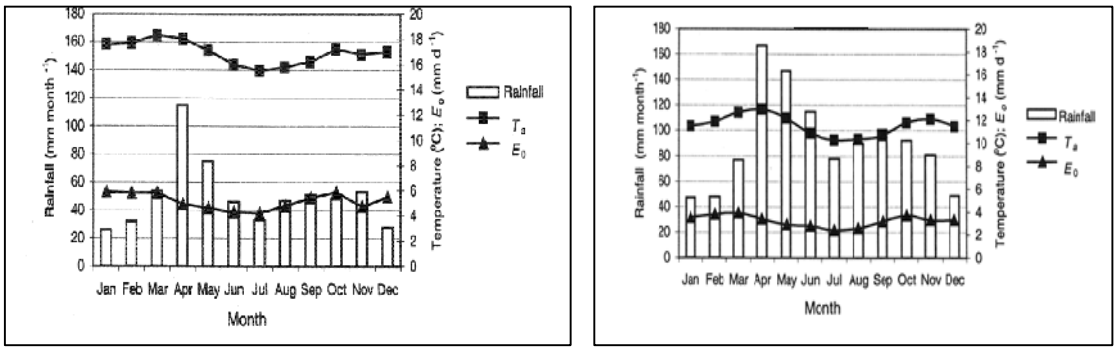


Figure 2: Monthly average rainfall, average daily temperature (1931-1983) and average daily reference E_o (1974-1983) at Naivasha town at altitude 1906 m and at North Kinangop at 2620 m (Source: Farah, 2001)

2.2 Vegetation

Landcover in the basin is greatly influenced by rainfall. The vegetation can be broadly classified into:

(vi) Forest,
(vii) Scrub/Bush-land/native,
(viii) Bare/range brush/moorland,
(ix) Grassland/scrubland, and
(x) Agricultural land (small intensive/sparse)

The land cover of the basin is broadly categorized into four groups, namely Agriculture, Grass, Bush/scrub land and Forest. In the Nyandarua ranges, predominant land cover classes are forest and crops. The main crops are maize, potatoes and wheat. In addition there are many other vegetables grown by smallholder farmers in the middle part of the basin. In the lower catchments, there are extensive areas of grass/scrubland and bush land, which are used for livestock grazing (Muthawatta, 2004).

2.3 Soils

The soils in Malewa basin can be described as complex due to the influence of extensive relief variation, volcanic activity and underlying bedrocks (Sombroek *et al,* 1980). Based on studies conducted in the area (Sombroek *et al* 1980, Siderius, 1998; Atkilt, 2001; and Nagelhout, 2001) soils can be grouped into three (3) groups such as; 1) soils developed from lacustrine deposits; 2) volcanic; and 3) lacustrine-volcanic. These soils are highly susceptible to both erosion and compaction (Kiai and Mailu, 1998). Prominent soil degradations in the area are due to wind and water erosion, sealing and compaction (Nagelhout, 2001). The fragility of the area and various human activities seems to accelerate land degradation in the west and southern area of the basin (Hennemann, 2001). From the Kenya soil terrain (SOTWIS Ver. 1), the soils of the study area can be classified into 10 different soil categories based on the FAO classification (Figure 3).

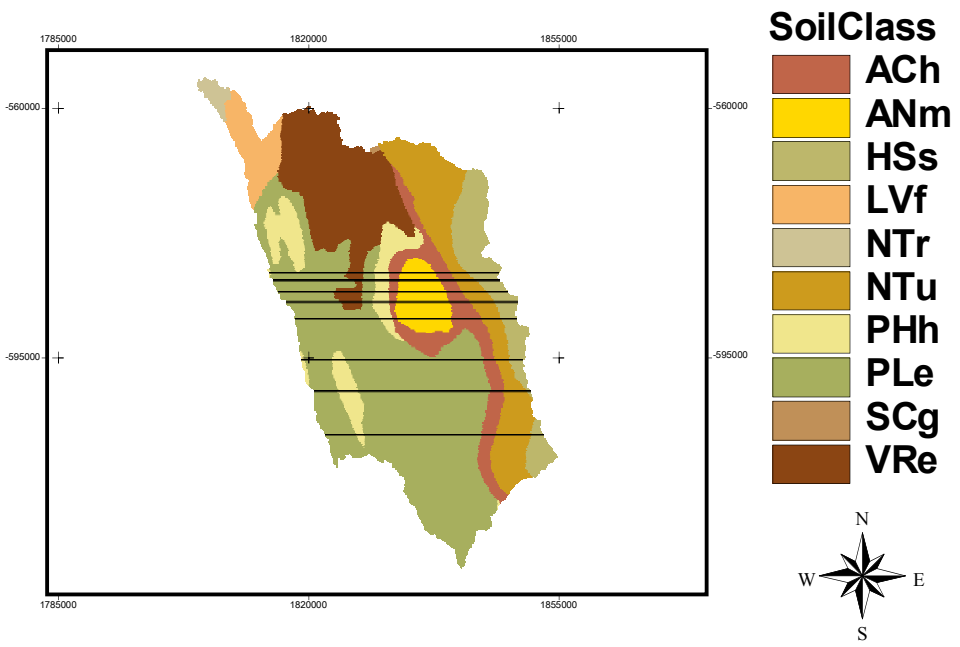


Figure 3: Soil distribution in study area

2.4 The Drainage Networks

The Malewa River Basin, including the Turasha river basin comprises an area of 1705 Km^2 which is approximately 50% of the larger Lake Naivasha Basin (3387Km^2). Drainage into the Malewa starts among the steep forested eastern slopes from the Kinangop plateau (2483m a.m.s.l.) and the Aberdares (3960+m a.m.s.l.) where the average annual rainfall is 1087.5mm (Salah, 1999). Initial flow takes place in a westerly direction via a number of steeply graded tributaries that, at the lower slopes of the range, develops into four main tributaries namely, Mugutyu, Turasha, Kitiri, and Mukungi. All flow north-south before turning west and joining the River Malewa. River Turasha is the most important tributary and joins the Malewa approximately 8km east of Gilgil town (Figure 4). The tributaries of the Malewa river forms a very dense dendritic drainage pattern except in the Kipipiri area where they have a radial flow pattern due to the conical shape of the volcanic Kipipiri range (Graham, 1998). River Wanjohi tributary and Malewa tributary flow northward before turning west the south from Ol Kalou.

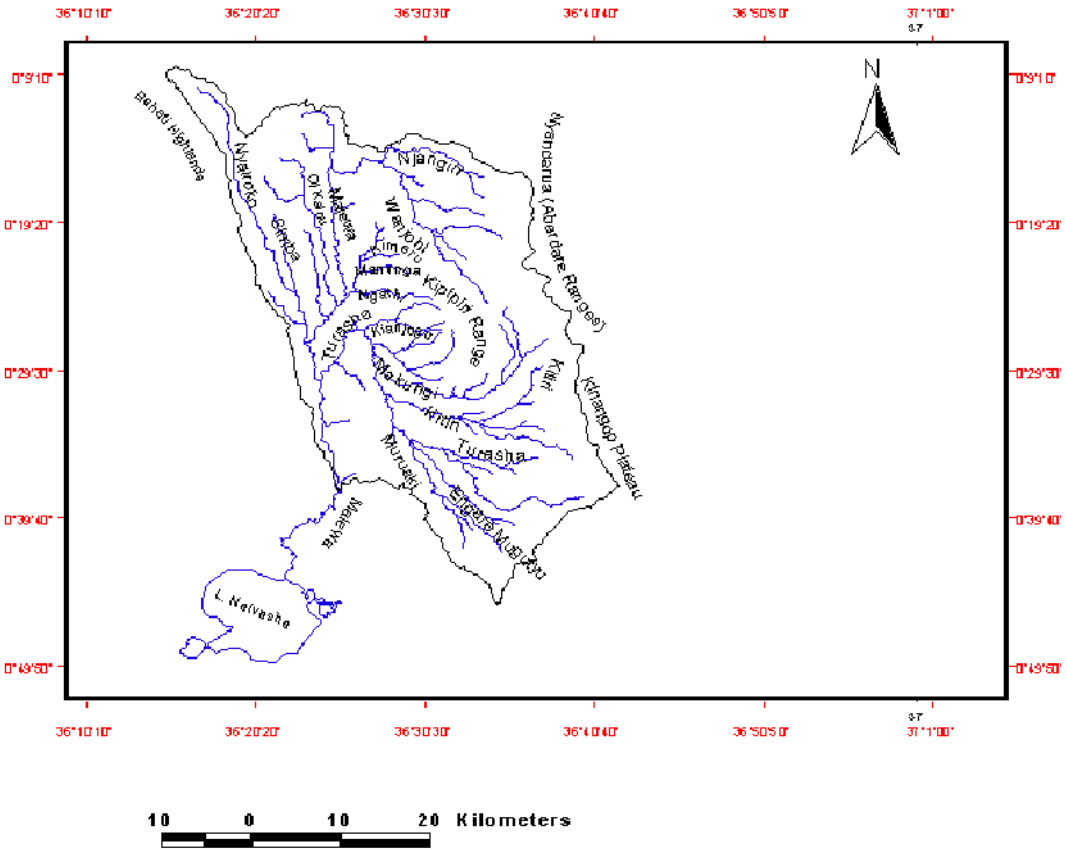


Figure 4: The Drainage Pattern of Malewa Watershed

3.0 Methods and Analysis

3.1 Hydrologic Model

For this study, the Soil and Water Assessment Tool (SWAT) was chosen The Soil and Water Assessment Tool is a river basin model that was developed for the USDA Agricultural Research Service, by Blackland Research Center in Texas (http://www.brc.tamus.edu/blackland/. Figure 5 presents a diagram of the SWAT process.

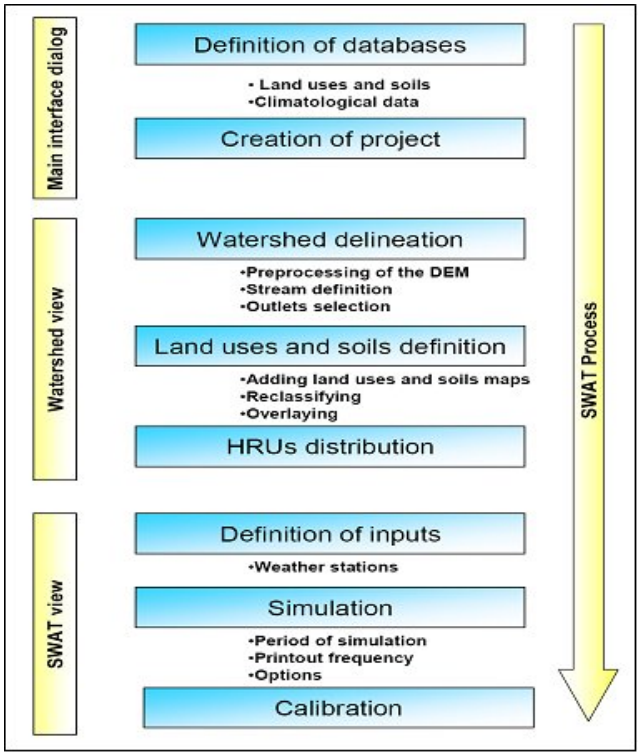


Figure 5: Representation of the SWAT model process

3.1.1 Input Data

Available data that were used for modeling are depicted in Table 1.

Table 1: Model input data sources for the Malewa Watershed

Data Types	Scale	Source	Data description/properties
Topo-sheets	1:50,000 and	Survey of Kenya	Boundary, drainage, geo-referencing
Soils (KENSOTER SOTWIS version	1:1M	ISRIC	Soil physical properties e.g. bulk density, texture, saturated
Land use	1:250,000	1980 Landsat data by the Japan International Co-operation Agency JICA	Land use classification valid for 1980
Weather		KMD	Daily precipitation and temperature,(9036002, 9036025, 9036054, 9036062, 9036182, 9036241, 9036281
Stream flow		Ministry of water and Irrigation	Daily stream flow (2GB01, 2GB03, 2GB04, 2GB05, 2GB07, 2GC04, 2GC05, 2GC07) for a
BMP			Pre- and post-management

3.2 Modeling Process

The preliminary step was the definition of the databases (dbf tables) i.e. soil and land use parameters, and climatological data. Each table had to be defined clearly using the nomenclature provided in the SWAT user's manual. The climatological data were added in different files presenting each parameter and the location of their meteorological station. Table 2 represents the look-up

table for the land use database. The land use mapped in the shapefile is linked to default categories present in SWAT.

Table 2: Relation between the land use map and the SWAT database

Land use shapefile	SWAT database
Forests, woodland	FRST Forest-Mixed
Agricultural Land	AGRL Agricultural Land – Generic
Infrastructures	UINS Institutional
Heath land, Brush land,	RNGB Range – Brush
Residential	URMD Residential – Medium Density
Marshland, peat bog	WETN Wetlands – Non Forested
Water	WETN Wetlands – Non Forested
Rocks	RNGB Range – Brush
Sands and Pebbles	FRST Forest-Mixed

The land use 'Water' exists in the SWAT database but it is advisable to use Wetlands because this special land use could create errors in the computation of the hydrological network (Renaud, 2004).

In this study, a yearly/monthly and daily printout on the period 1972 – 2003 was used. From the 1st Precipitation of January 1972, to the 31st Precipitation of December 2003, the outputs were then fully simulated. The outputs of SWAT are in different types: grids, shape files and tables. The results are presented in four main tables:

- Summary output file
- HRU output file
- Sub-basin output file
- Main channel/reach output file.

3.3 Sensitivity Analysis

Large complex watershed models contain hundreds of parameters that represent hydrologic and water quality processes in watersheds. Model predictions are more sensitive to perturbation of some input parameters than others, even though the insensitive parameters may bear a larger uncertain range. Thereby, adjustment of all model parameters for a given study area not only is cumbersome, but is not essential. Sensitivity analysis was done through the SWAT model sensitivity analysis tool. The observed flow data used was at the basin outlet 2GB01. Table 3 show amongst many SWAT parameters that are adjusted during sensitivity analysis process

Table 3: SWAT Parameters

	Parameter	Description	Min	Max	Units	SWAT
1	CN2	Initial SCS runoff curve number for moisture	35	98		MGT
2	SLOPE	Average slope steepness	0	0.6	M/m	HRU
3	SLSUBBS	Average slope length	10	150	m	HRU
4	ESCO	Soil evaporation compensation factor	0	1		HRU
5	CH-N1	Manning's "n" value for tributary channels	0.008	30		SUB
6	CH-S1	Average slope of tributary channels	0	10	m/m	SUB
7	CH-K1	Effective hydraulic conductivity in tributary channel alluvium	0	150	Mm/hr	SUB
8	CH-N2	Manning "n' value for the main channel	0.008	0.3		RTE
9	CH-S2	Average slope of the main channel along the	0	10	m/m	RTE
10	CH-K2	Effective hydraulic conductivity in main	0	150	Mm/hr	RTE
11	GWQMN	Threshold depth of water in shallow aquifer for return flow to occur	0	5000	Mm	GW
12	ALPHA-	Base flow alpha factor	0	1	Days	GW
13	GW-	Ground water delay time	0	500	Days	GW
14	GW-	Ground water "revap" time	0.02	0.2		GW
15	SOL-AWC	Available water capacity of the soil layer	0	1	Mm/m	SOL
16	CH-EROD	Channel erodibility factor	0	0.6	Cm/hr/p	RTE
17	CH-COV	Channel cover factor	0	1		RTE
18	SPCON	Linear coefficient for calculating maximum sediment re-entrained	0.001	0.01		BSN
19	SPEXP	Exponent	1	1.5		BSN
20	PRF	V peak rate adjustment factor for sediment routing in channel network	0	2		BSN
21	USLE-P	USLE equation support practice factor	0.1	1		MGT
22	USLE-C	Maximum value of USLE equation for cover factor for water erosion	0.001	0.5		CROP DAT
23	SOL-LABP	Initial soluble P concentration in soil layer	0	100	Mg/kg	CHM
24	SOL-	Initial soluble P concentration in soil layer	0	4000	Mg/kg	CHM
25	SOL-	Initial NO3 concentration in soil layer	0	5	Mg/kg	CHM
26	SOL-	Initial organic N concentration in soil layer	0	1000	Mg/kg	CHM
27	RS1	Local algae settling rate at 20^{0c}	0	2	m/day	SWQ
28	RS2	Benthic (sediment) source rate for dissolved P in the reach at 20^{0c}	0.001	0.1	Mg/m^2day	SWQ
29	RS4	Rate coefficient for organic N settling in the				
30	RS5	Organic P settling rate in the reach at 20^{0c}				
31	BC4	Rate constant for mineralization of P to dissolve P in the reach at 20^{0c}				
32	A10	Ratio of chlorophyll –a to algae biomass				
33	A11	Fraction of algal biomass that is nitrogen				
34	A12	Fraction of algal biomass that is				
35	RHOQ	Algal respiration rate at 20^{0c}				
36	K-P	Michaelis menton rate saturation				

3.3.1 Model Calibration

Calibration of a watershed model is essentially the exercise of adjusting model parameters such that model as described by Beck *et al*. (1997):

(iv) soundness of mathematical representation of processes,
(v) sufficient correspondence between model outputs and observations, and
(vi) Fulfillment of the designated task.

Procedure provided by (Santhi *et al*., 2001b) was followed.

Simulation runs were conducted on a daily/monthly basis to compare the modeling output with the corresponding observed discharge. The calibration considered fourteen model parameters that can be summarized in three groups: (1) Parameters that govern surface water processes, including curve number (CN), soil evaporation compensation factor (ESCO), plant uptake compensation factor (EPCO), and available water capacity of the soil layer (SOL_AWC; (2) Parameters that control subsurface water processes, including capillary coefficient from groundwater (GW_REVAP),

groundwater delay (GW_DELAY), and deep aquifer percolation fraction (RCHRG_DP); And (3) parameters that influence routing processes, including Manning's roughness coefficient in main channel routing (CH_N(2)) (Neitsch *et al.*, 2002). One parameter was adjusted while others were kept unchanged.

3.3.2 Model validation

Data for a period of twenty-one years from January 1st, 1981 to December 31st, 1995 was used for validating the SWAT model for the Malewa River Basin.

3.3.3 Model Evaluation Criteria

The accuracy of SWAT simulation results was determined by examination of the coefficient of determination (R^2) and the Nash and Sutcliffe model efficiency coefficient (E_{NS}) (Nash and Sutcliffe, 1970). The R^2 value indicates the strength of the linear relationship between the observed and simulated values. The E_{NS} simulation coefficient indicates how well the plot of observed verse simulated values fits the 1:1 line. The E_{NS} can range from 2:1 to 1:1, with 1 being a perfect agreement between the model and real data (Santhi *et al.*, 2001). E_{NS} is defined equation 3.1 as

$$\mathbf{E_{NS} = 1 -} \left[\{\sum_{i=1}^{n}(Measured_i - simulated_i)^2\} / \sum (measured_i - \frac{1}{n}\sum_{i=1}^{n} measured_i)^2\right] \qquad \textbf{Equation 3.1}$$

E_{NS} values range from 1.0 (best) to negative infinity. E_{NS} is a more stringent test of performance than R^2 and is never larger than r^2. E_{NS} measures how well the simulated results predict the measured data relative to simply predicting the quantity of interest by using the average of the measured data over the period of comparison. A value of 0.0 for E_{NS} means that the model prediction are just as accurate as using the measured data average to predict the measured data. E_{NS} value less than 0.0 indicate the measured data average is better predictor of the measured data than the model predictions while a value greater than 0.0 indicates the model is a better predictor of the measured data than the measured data average. The simulation results were considered to be good if $E_{NS} \geq 0.75$, and satisfactory if $0.36 \leq E_{NS} \leq 0.75$ (Van Liew and Garbrecht, 2003).

3.4 Scenario Analysis

The following scenarios (Table 4) were adopted for the study of implementing best management practices (BMPs) on Geta and Wanjohi subbasins of Malewa.

Table 4: Scenarios Adopted for the BMPs on Wanjohi and Geta subbasins

1	Best Management practice	This scenario involved implementing two BMP. a) Filter strip (0, 1, 5, 10 m edge). This scenario involved altering the filter width from no filter width 0m to 1, and running the scenario, then 1m, 5m, and 10m respectively. Each scenario was compared with base scenario 0m c. Contours (P=0.1, P=0.65, and P=1). This scenario involved implementing contouring practices. In order to achieve this, the P in the support practice factor in USLE equation was modified from base condition 1 with no erosion control to erosion controlled structure with USLE-P value of 0.1, and 0.65 respectively.

4.0 Results and Discussions

Table 4 gives the scenarios adopted in evaluating the impacts of implementing BMPs in some selected subbasins of Malewa basin namely Geta and Wanjohi subbasins.

Table 4: Best Management Practices (BMPs) scenarios adapted for studying Impacts of Land-use change on Malewa Watershed

BMP	**Base**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**
Filter strip	Base Filter	Filter width	Filter width	Filter width	Filter width (0	Filter width (0
Contour farming	Base USLE_P P=1	USLE_P P=1	USLE_P P=1	USLE_P P=1	USLE_P P=0.1	USLE_P P=0.65

Note: P is the support practice factor in USLE equation. Numerical values of *P-USLE* for these practices (Support practices include contour tillage, strip cropping on the contour and terrace systems) are given in Wischmeier and Smith, (1978) and reiterated by Neitsch *et al*., (2002) as used in the SWAT.

4.1 Impacts of Best Management Practices on Water Quantity and Quality

4.1.1 Effects of BMPs on Streamflow

The effect of implementing the best management practices (BMPs) on runoff volume and streamflow at the outlets of the two selected target areas are presented in Figures 6 for Wanjohi sub-basin and Figure 4.2 for Geta sub-basin respectively. USLE_P was modified to represent parrallel terrace/contouring with P value set at 0.1 and 0.65, filter strip was represented in the model by modifying filter width to 1 m, 5 m and 10 m. In the study area there are neither installed BMPs nor existing ones nor any data for analysis, hence it necessitated the use of SWAT model for simulating the impacts of implementing the BMPs on the selected priority sub-basins.

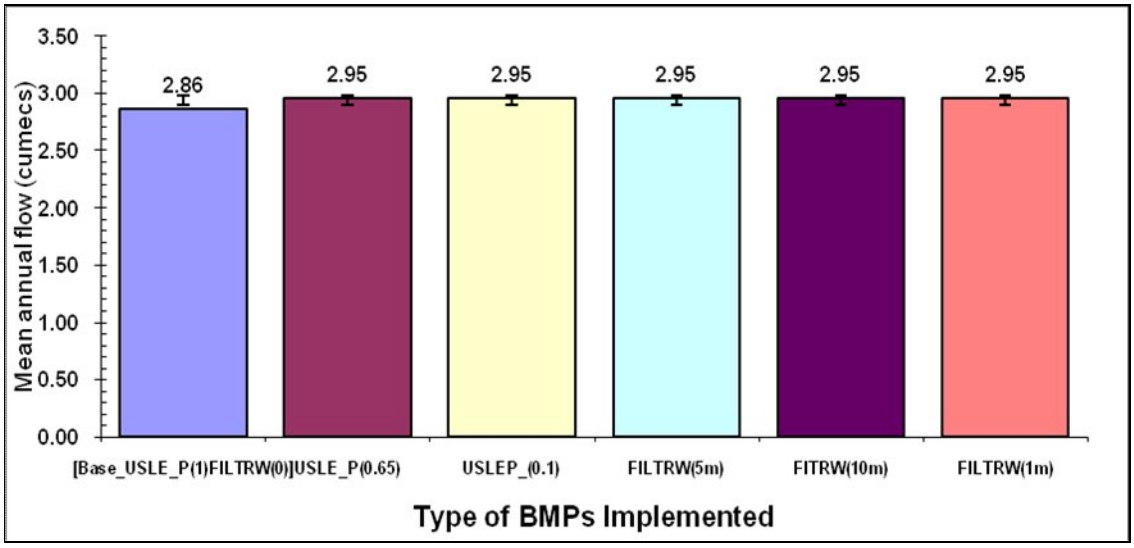


Figure 6: Impacts of BMPs on Streamflow at Wanjohi area
(Error bars with standard deviation)

The results shows that with the installation of BMPs in the Wanjohi catchment, streamflow increased from a mean of 2.86 cumecs in base scenario to 2.95 cumecs with all the BMPs installed in Wanjohi sub-basin. The results from Geta catchment (Figure 7) are however completely the

opposite. The implementation of BMPs resulted in a reduction of streamflow though marginally compared to base scenario i.e. from 3.1 to 3.0 cumecs.

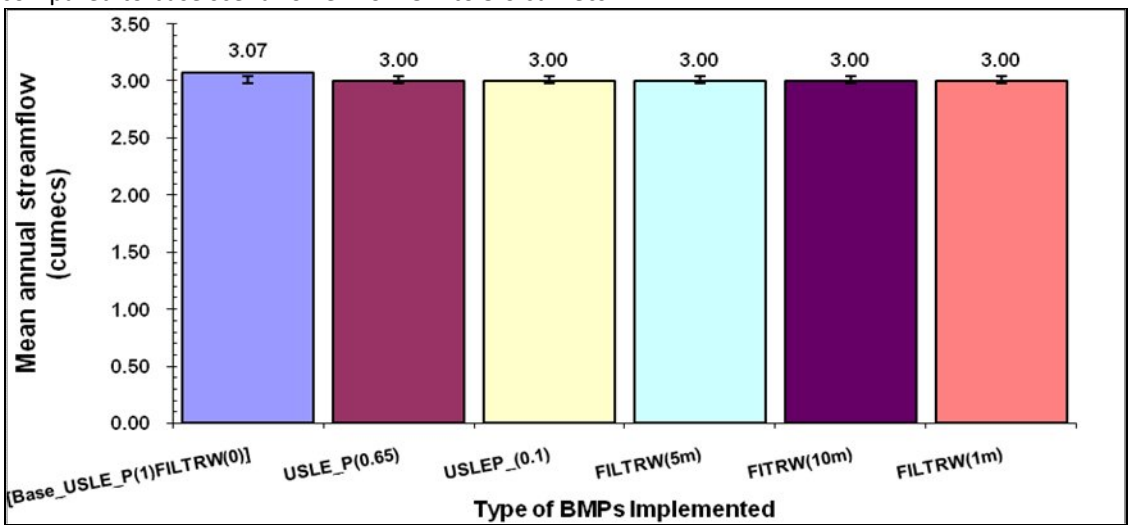


Figure 7: Impacts of BMPs on Streamflow at GETA area (Error bars with standard deviation)

These difference in results for Geta subbasin can be attributed to varying land slopes. In Geta, there are more steep slopes (>10%) compared to Wanjohi area. When the slopes exceed 10%, the effectiveness of filter strips and contour farming (contour tillage, strip cropping on the contour and terrace systems) are drastically reduced. This calls for introduction of more advanced conservation measures such as grade stabilization or bench terraces since contour farming practice applies on sloping land where crops are grown and is most effective on slopes between 2 and 10 percent.

Implementation of Best Management Practices (BMPs) is a conventional approach for controlling nonpoint sources of sediments and nutrients. However, implementation of BMPs is rarely followed by a good long-term data monitoring program in place to study how effective they have been in meeting their original goals. Long-term data on flow and water quality within watersheds, before and after placement of BMPs, is not generally available. Therefore, evaluation of BMPs (especially new ones that have had little or no history of use) must be necessarily conducted through watershed models.

4.1.2 Effects of BMPs on Sediment Yield

The simulated effect of filter strip and contour terrace on sediment output at the outlets of the two selcted areas are depicted in Figure 8 for Wanjohi sub-basin and Figure 9 for Geta Sub-basin respectively.

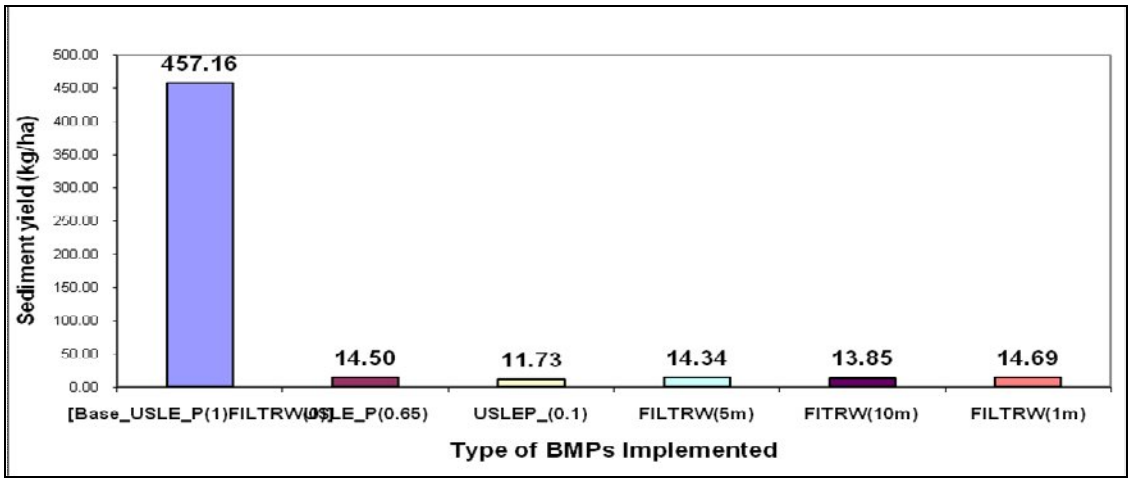


Figure 8: Impacts of BMPs on Sediments at Wanjohi area

The results show that the BMPs decreased the average monthly sediment yield at Wanjohi sub-basin outlet from 457.16 kg/ha (without BMPs) to 11.73 kg/ha for the best BMP (USLE_P=0.1 which is equivalent to contour terrace). Other BMPs had similar reductions ranging from 14.69 kg/ha for filter width of 1 m , 13.85 kg/ha for filter width of 10 m, 14.34 kg/ha for filter width of 5 m and 14.5 kg/ha for contour terrace with USLE_P value of 0.5. The introduction of filter strip had a significant effect in sediment yield reduction. Changing the filter strip from 5 m width to 10 m width had very little change on sediment yield reduction.

When BMPs are implemented in Geta Figure 9, there is a substantial decrease in sediment yield from 424.56 kg/ha with no BMPs to 18.9 kg/ha with contour terrace in place (USLE_P value of 0.50, 15.52 k/ha for contour terrace with USLE_P value of 0.1, 15.52 kg/ha, 18.74kg/ha and 19.08 kg/ha for filter widths of 5m, 10m and 1m respectively. The results show that sediment trapping efficiency improves with increasing buffer width.

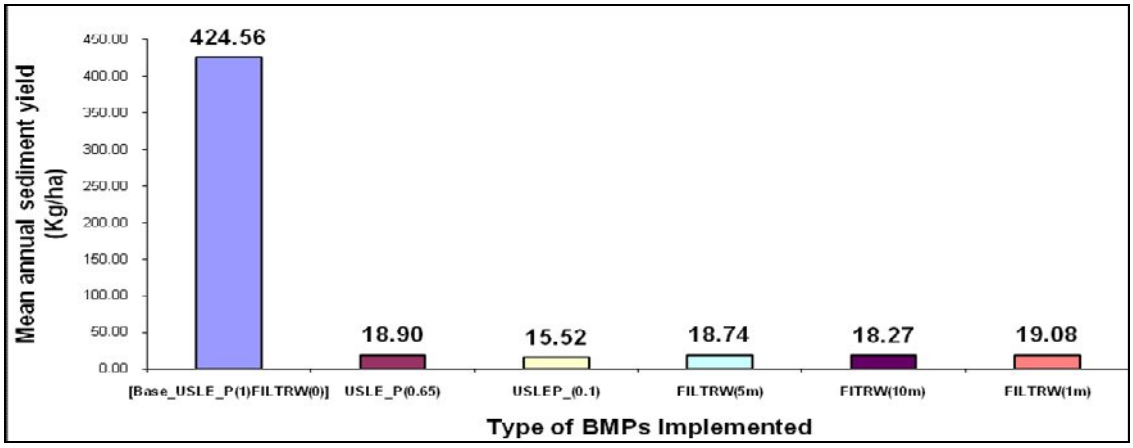


Figure 9: Impacts of BMPs on Sediments at GETA area

Further analysis was done to see the efficiency of the implemented BMPs. An overall evaluation was made by estimating BMP efficacy in terms of percentage reduction of the parameter (Equation 4.2):

$$\text{Reduction (\%)} = \frac{\text{Model output (Without BMPs)} - \text{Model output (With BMPs)}}{\text{Model output (Without BMPs)}}$$ **Equation 4.2**

The efficacy of the BMPs for abating sediment yield in the selected areas calculated using equation 4.2 is given in Table 5.

Table 5: The efficacy of BMPs simulated in the study sub-basin areas

		% Reductions				
Sub-basin	**Measured output**	**Contour terrace**	**Contour terrace**	**Filter width**	**Filter width10m**	**Filter width**
Wanjohi	FLOW_OUT	-0.43	-3.31	-3.32	-3.32	-3.32
	SED_OUT	96.83	97.43	96.86	96.97	96.79
	ORGN_OUT	97.33	99.25	98.3	98.86	97.37
	ORGP_OUT	96.86	99.1	98.03	98.68	96.95
	NO3_OUT	91.9	91.84	92.29	92.68	92.05
Geta	FLOW_OUT	2.52	2.52	2.51	2.51	2.51
	SED_OUT	95.55	96.34	95.59	95.7	95.51
	ORGN_OUT	-21.87	64.63	24.04	49.17	-17.74
	ORGP_OUT	60.56	88.54	75.43	83.56	61.92
	NO3_OUT	99.07	99.06	99.18	99.28	99.11

Table 5 presents the efficacy results of implementing BMPS as percentage reductions in average annual sediment, total nitrogen (organic and mineral nitrogen) and total phosphorus (organic and mineral phosphorus) loadings at Geta and Wanjohi sub-basins outlets. The results indicate a significant reduction in sediment, total N and total P with implementation of BMPs. The decrease could be due to lesser sheet erosion from upland areas.

4.1.3 Effects of BMPs on Nutrient Yield

The results of the effects of BMPs on nutrient yield are presented as percentage reductions in average annual total nitrogen (organic and mineral nitrogen) and total phosphorus (organic and mineral phosphorus) loadings at the selected subbasins (Geta and Wanjohi). Loadings generated in the pre-BMP conditions were used as the base to estimate the percentage load reductions. Figure 10 and Figure 11 presents the results of the simulated total organic N yields at the Wanjohi and Geta outlets respectively.

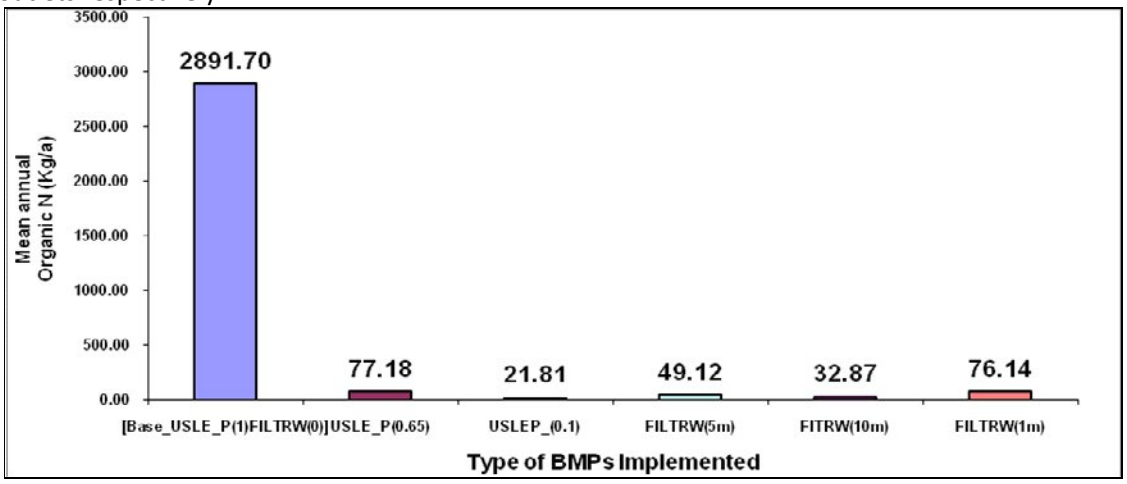


Figure 10: Impacts of BMPs on Organic N at Wanjohi area

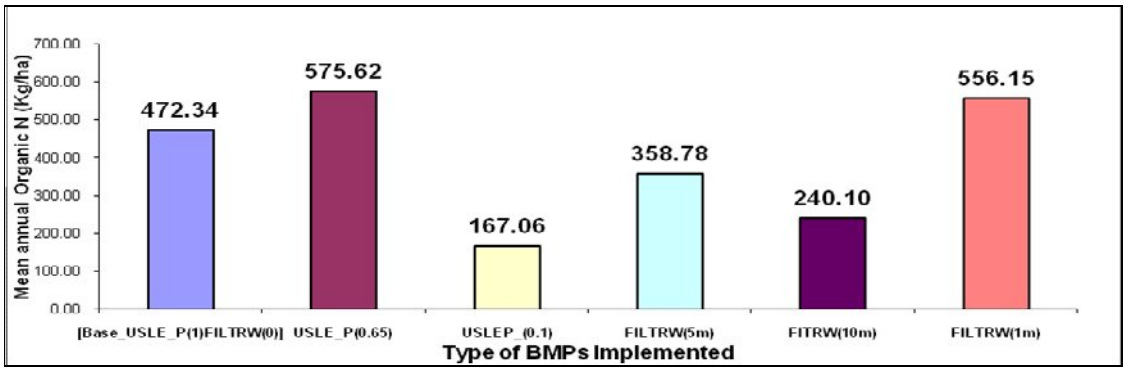


Figure 11: Impacts of BMPs on Organic N at Geta area

The results of installing BMPs in the watersheds indicates that without BMPs, total organic N yield predicted by the SWAT were 2891 Kg/ha for Wanjohi and 472 Kg/ha for Geta. After the implementation of the BMPs, there was a significant decrease in organic N in both sub-basins. The decrease for Wanjohi sub-basin was from 2891 kg/ha to 77.18, 21.81, 49.12, 32.87 and 76.14 kg/ha for contour terrace (USLE_P=0.5), contour terrace (USLE_P=0.1), and filter widths of 5m, 10, and 1m respectively. The decrease for Geta was from 472.34 kg/ha to 167.06 kg/ha for contour terrace (USLE_P=0.1) and 358.78kg/ha and 240.1kg/ha for filter width of 5m and 10m respectively. Contour terrace having USLE_P value of 0.5 and filter width of 1m were not effective in Geta sub-basin. The organic N increased from 472.34 in base conditions to 575.62 for USLE_P=0.5 and to 556.15kg/ha for filter width of 1m respectively. Filter strips are based on the filter strip's ability to trap sediment and nutrients based on the strip's width. The shorter the width, the lower the trapping efficiency is. In Geta sub-basin, the slopes are steep hence the ineffectiveness of the 1m width filter strip.
The results of the total P predictions of the model results for selected priority sub-basins with BMPs implemented are presented in Figure 12 for Wanjohi and Figure 13 for Geta.

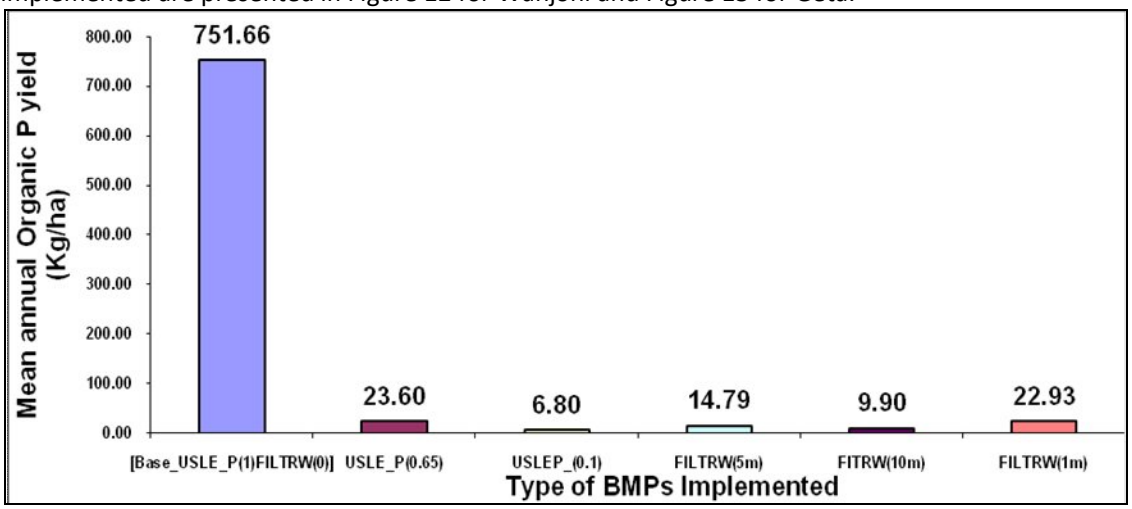


Figure 12: Impacts of BMPs on Organic P at Wanjohi outlet

The installed BMPs Figure 12 reduced the total P output from the sub- basins. For Wanjohi area, total P was reduced from 751.86 kg/ha to 23.6 kg/ha with contour terrace of USLE_P value 0.5and 6.8 kg/ha for contour terrace of USLE_P value of 0.1. The total phosphorous P values were also reduced with filter width put in-place. These reductions were as 14.79 kg/ha, 9.90kg/ha, and 22.93 kg/ha for filter widths of 5 m, 10 m and 1 m respectively.

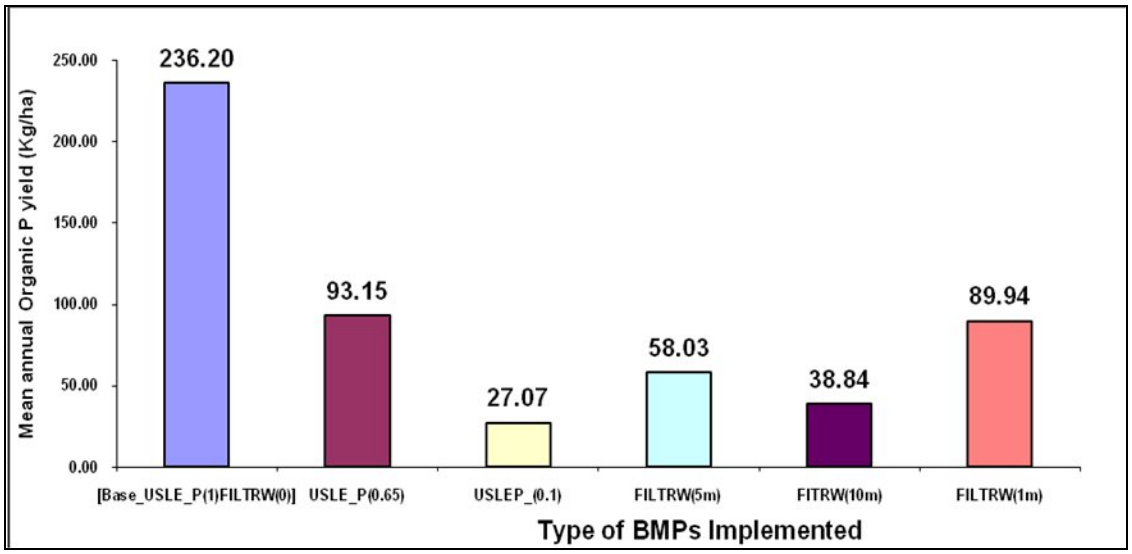


Figure 13: Impacts of BMPs on Organic P at Geta area

Figure 13 shows the results of impacts BMPs on organic P at Geta sub-basin outlet. The reductions were from 236.2kg/ha to 93.15kg/ha and 27.07kg/ha for contour terraces having USLE_P values of 0.5 and 0.1 respectively. The reduction of organic P achieved with filter widths of 5m, 10m, and 1m were as follows, 58.03kg.ha, 30.84kg/ha and 89.94 kg/ha respectively. The installed BMPs were estimated to effectively reduce N and P yields between 99-24% and 99-51% respectively (Table 5 for the two selected areas. It's worth noting that field border strip of 1 m and USLE_P of 0.5 were not effective in the Geta area. This is due to steep slopes found within the Geta sub-basin.

Most of the nutrients (total P, and total N) are introduced into the main channel and transported downstream through surface runoff and lateral subsurface flow. Major phosphorous sources are from mineral soil which include organic phosphorus available in humus, mineral phosphorus that is not soluble, and plant available phosphorus. Phosphorus may be added to the soil from agricultural lands in the form of fertilizer, manure, and residue application. Surface runoff is the major carrier of phosphorous out of most catchments (Sharpley and Syers, 1979). Major nitrogen sources in mineral soil include organic nitrogen available in humus, mineral nitrogen in soil colloids, and mineral nitrogen in solution. Nitrogen may be added to the soil from agricultural lands in the form of fertilizer, manure, or residue application. Plant uptake, denitrification, and volatilization, leaching, and soil erosion are the major mechanisms of nitrogen removal from a field. In the study area, soil erosion and leaching can be said to be the major mechanisms of nitrogen removal.

From the results of implementing BMPs, it can be noted that the reduction in total P load was consistent with the reduction of sediment yield at the outlet of the watersheds (Figure 8, Figure 9, Figure 12 and 13). This was anticipated for two reasons. First, in relatively small watersheds like Wanjohi and Geta, the role of in-stream nutrient processes that are simulated by SWAT, such as algal decay on phosphorus yield, is negligible compared to soil loss from upland areas and secondly due to channel erosion. In such watersheds, it can be claimed that sediment and nutrient yields are correlated. Moreover, the BMPs installed in the study watersheds were basically sediment control structures. The impact of the BMPs on nutrient loads was as a consequence of reduction of sediment yield. With installation of conservation structures such as filter strips, contour farming e.g. contour tillage, strip cropping on the contour and terrace systems, etc will enhance water quality coming from the upland areas of the catchment.

In summary, upstream land use practices have important impacts on water resources such as good water quality, less sediments, or more regular water flow for downstream users. However, much controversy exists about the direction and magnitude of such impacts. Payment for environmental services by downstream users to upstream users depends much on perceived and agreed upon mechanism for sharing of resulting benefits and costs by all recourse users in a watershed context. The study has focused on few management systems e.g. filter strips and contour farming systems that could be adopted in the study area in order to improve on the water quality and water flowing downstream. These management systems can be incorporated into the PES system which is a promising mechanism of improving the conditions of water resources in watersheds. For specific case of PES schemes in watersheds, the service usually relates to the maintenance of the availability and/or quality of water. The providers are upstream land users, whose land use is to be modified or conserved to render the service, and the users are downstream consumers – companies or individuals – of the water resources. For PES to have the desired effects they must reach land users in a way that motivates them to change their land use practices to more sustainable ones and for starting, the two management systems i.e. contour farming and 5m width filter strip will provide a beginning for implementation.

5.0 Conclusions and Recommendation

5.1 Conclusions

- The best management practices (BMPs) that were simulated in the selected sub-basins were represented in the model by altering corresponding model parameters. Model simulations were performed at various watershed subdivision levels. Comparisons of sediment and nutrient predictions with and without implementation of the BMPs were used to determine the efficiency of the BMPs at each watershed subdivision level. USLE support practice factor (USLE_P) accounts for the impacts of specific support practice on soil loss from a field. Support practices such as contour tillage, strip cropping on the contour, and terrace systems the default value for USLE_P is unity, this value was altered to 0.1, and 0.65 for the HRUs to implement the contour practice. The result shows that Filter strip and contours are effective in reducing the nutrient and sediment pollutant loads. Of the two best management practices simulated, filter strip offers the best alternative for reducing pollutant loads and should be encouraged for adoption by the upper catchment farmers.
- Filter strips were found to have varying effectiveness at reducing overland flow, sedimentation, and removing nutrients. The hydrologic benefit of riparian buffers increases with width.
- Considerable reductions in sediment concentrations occur when 5m wide filter strips are simulated. However, increasing the filter strips by an additional 5m (total 10 m) does not produce the same level of reductions as was observed for the 0 to 5m condition. This suggests that benefits from implementing filter strips will taper off for further increases in filter width.
- Reductions were slightly higher for sub-with moderate slope gradient compared to sub-basins with steep slopes. Also headwater sub-basins recorded greater reductions in sediment exports (e.g., 17, 13) compared to sub-basins located downstream (e.g., 23 and 19). Clearly greater improvements in water quality could be achieved by targeting headwater sub-basins.
- The impact of simulating filter strips on the sediment load at the main watershed outlet was also determined. The 5m filter scenarios produces a 17% reduction in sediment load, whereas doubling the filter widths only decreases the load by an additional 5%.

5.1 Recommendations

- There is need to do economic evaluation of BMPs on the Malewa watershed before embarking on their implementations and there is need to do further research on the best placement of the BMPs within the Malewa catchment.
- Implementing Best Management Practices (BMPs) in Malewa catchment will minimize the potential for agricultural nonpoint source water pollution and other adverse environmental and social problems. BMPs are practices based on the best available research and scientific data. They permit efficient farming operations while achieving the least possible adverse impact upon the environment or human, animal and plant health. Selection, design and implementation of appropriate BMPs require evaluation of resources involved, and the potential impacts on them. BMPs also require evaluation of the needs for sustainable agriculture, farm operations and markets and existing practices.

References

Atkilt, G. (2001). Soil Survey to Predict Soil Characteristics Relevant to Land Management (Naivasha, Kenya). MSc Thesis. ITC. Soil Science Division. Enschede, 154 pp.

Becht R. and Sarah H., (2003). Sharing experience and early lessons in GEF and non-GEF lake basin management projects Lake Naivasha brief Prepared for the ILEC foundation of Japan, October 2003.

Beck, M. B., Ravetz, J. R., Mulkey, L. A., Barnwell, T. O. (1997). On the problem of model validation for predictive exposure assessments, *Stochastic Hydrology and Hydraulics*, **11**(3).

Betch, R., and D., Harper. (2002). Towards an understanding of human impact upon the hydrology of Lake Naivasha, *Hydrobiologia,* **488**, pp 1-11.

Clarke, M. C., G. D. G., Woodhall, D. Allen and Darling, G. (1990). Geological, volcanic and Hydrological Controls on the occurrence of geothermal Activity in the area surrounding Lake Naivasha, Kenya Ministry of Energy, Nairobi.

Daniel, J.G., Kulasingam, A. (1975). Problems arising from large scale forest clearing for agricultural use-the Malaysian experience. *Planter, Kuala Lumpur* **51**, pp 250-257.

Duncan, M. (2003). Clarification of the effect of vegetation change on water yield prepared for Environment Canterbury, technical report U03/8.

FAO, (2004). *Land-Water Linkages in Rural Watersheds Electronic Workshop–Synthesis Report*, Rome, FAO, 18 September–27 October.

http://www.fao.org/ag/agl/watershed/watershed/papers/paperewk/pewrken/synthesis.pdf> accessed on 6th September 2006.

Farah, H.O., (2001). Estimation of regional evaporation under different weather conditions from satellite and meteorological data: A case study in the Naivasha basin, Kenya. PhD Thesis, Wageningen University, the Netherland.

Graham, A., (1998). Groundwater recharge estimation of the Malewa catchment, Naivasha, Kenya, Enschede, ITC.

Green, W. H., and G. A. Ampt. 1911. Studies on soil physics 1: The flow of air and water through soils. *Journal of Agricultural Sciences,* **4**(1), pp 1-24.

Hargreaves G. H., Z.A. Samani. (1985). Reference crop evapotranspiration from temperature Appl. *Eng. Agric*., **1,** pp 96-99.

Hennemann, R. (2001a). Elective on Land Degradation, Assessment, Monitoring and Modelling. Soil Science Division, ITC, Enschede, the Netherlands.

Hennemann, R. (2001b) Some Notes About Soil and Land Degradation in the Naivasha Rangeland Zone, pp. 3. Soil Science Division, ITC, Enschede, the Netherlands.

Inamdar, S (2004). Assessment of Modeling Tools and Data Needs for Developing the Sediment Portion of the TMDL Plan for a Mixed Watershed. Final Report to the Great Lakes Basin Program. Buffalo, New York, 10-12.

Institute of Hydrology. (1990). Eucalyptus: Forest friend or foe? In Report of the Institute gf Hydrology for 1988/89. Wallingford, UK.

Kamoni, P. T. (1988). Detailed soil survey of a part of quarantine farm-National Husbandry Research Station, Naivasha, Nakuru District, pp. 24. Kenya Soil Survey, Nairobi.

Kiai, S. P. M. and Mailu, G. M. (1998). Wetland classification for agricultural development in Eastern and Southern Africa. FAO, Harare, Zimbabwe.

Mockus, V., (1969). Hydrologic Soil-Cover Complexes. *In:* National Engineering Handbook, Section 4: Hydrology. U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., pp. 10.1-10.24.

Motovilov, Y., L.Gottschalk, K. Engeland, A. Rodhe (1999). Validation of a Distributed Hydrological Model against Spatial Observations. Agricultural and Forest Meteorology 98-99, 257-277.

Muthawatta, P.L., (2004). Long term rainfall-runoff-Lake level modeling of the Naivasha Basin, Kenya, Enschede, ITC.

Nagelhout, A. (2001). Performance Analysis of Small Format Aerial Photography (SFAP) in Assessing Current Status and Trends in Wind Erosion: A case study in the Longonot-Kijabe Hill Area, Naivasha District, Kenya. MSc thesis, ITC.

Nash, J. E., J. V. Sutcliffe. (1970). River flow forecasting through conceptual models, Part I-a discussion of principles, *J.Hydrol*.**10**, pp 282-290.

Neitsch, S. L., J. G. Arnold, J. R. Kiniry, R. Srinivasan, and J. R. Williams (2002). Soil and Water Assessment Tool User's Manual: Version 2000. GSWRL Report 02-03, BRC Report 02-07, Published by Texas Water Resources Institute TR-193, College Station, TX.

Ojiambo, B. S., (1992). Hydrogeologic, Hydrochemical and Stable Isotopic Study of Possible Interactions between Lake Naivasha, Shallow Subsurface and Olkaria Geothermal.

Priestley, C. H. B., R. J. Taylor (1972). On the assessment of surface heat flux and evaporation using large scale parameters. Mon. *Weather Rev*. **100**, pp 81-92.

Rahim, A. N. (1987). The impact of forest conversion on water yield in Peninsular Malaysia. Paper presented at the workshop on impact of operations in natural and plantation forest on conservation of soil and water resources. Serdang.pp.2326.

Rykiel, E. J. (1996). Testing ecological models: the meaning of validation, Ecological Modeling, 90: 229-244.SAF, (2004) Loss of forest land. A position statement of the society of American foresters Retrieved on December 07, 2006, from http://www.safnet.org/policy and press/psst/loss-of-forest-land.cfm.

SAF (2004). Loss of forest land. *A position statement of the society of American foresters* Retrieved on December 07, 2006, from http://www.safnet.org/policy and press/psst/loss-of-forest-land.cfm.

Salah Ahamad, (1999). Sustainable use of water among competing sectors: A study in the Naivasha catchment, Rift Valley Province, Kenya, Enschede, ITC.

Santhi, C., Arnold, J. G., Williams, J. R., Dugas, W.A., Hauck, L. M., (2001a). Application of a watershed model to evaluate management effects on point and nonpoint pollution. Transactions of the American Society of Agricultural Engineering 44 (66), 1559e1770.

Santhi, C., Arnold, J. G., Williams, J. R., Dugas, W. A., Srinivasan, R., Hauck, L. M.,(2001b). Validation of the SWAT model on a large river basin with point and nonpoint sources. Journal of the American Water Resources Association 37 (5), 1169e1188.

Sharpley, A. N. and Syers, J. K (1979). Phosphorus input into a stream draining an agricultural watershed: II. Amounts and relative significance of runoff types, *Water, Air and Soil Pollution,* **11**, pp 417-428.

Shuttleworth, W. J. (1992). Evaporation. Chapter 4 In: *Handbook of Hydrology*, D.R. Maidment (Ed.), McGraw- Hill, Inc., New York, NY, pp. 4.1- 4.53

Siderius, W. (1998). Soils of The Lake Naivasha Environs. In: Contribution to the article in ITC journal, pp. 8. Soil Science Division, ITC, Enschede, The Netherlands.

Sombroek, W. G., H. M. H. Braun and van der Pouw, B. J. A. (1980). The explanatory soil map and agro-climatic zone map of Kenya. Report No. E.I, Kenya Soil Survey, Nairobi, 56 pp.

Van Liew, M. W. and Garbrecht, J. (2003). Hydrologic simulation of the Little Washita River Experimental Watershed using SWAT*. J. Am. Water Resour. Assoc*. **39**(2), pp 413-426.

Williams, J. R. and Berndt, H. D. (1977). Sediment yield prediction based on watershed hydrology, Trans. ASAE 20(6):1100-1104.

Wischmeier, W. H., and Smith, D. D. (1978). Predicting rainfall erosion loss: A guide to conservation planning. Agricultural handbook 537. U. S. Department of Agriculture, Washington, D.C.

ASSESSING THE EFFICIENCY OF SUBSURFACE CONSTRUCTED WETLANDS PLANTED WITH DIFFERENT MACROPHYTES IN REMOVING HEAVY METALS FROM WASTEWATER

P. G. Home, T. N. Njenga, T. G. Kinuthia, E. Kimutai, H. Mango and J. W. Kaluli
Biomechanical and Environmental Engineering Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail:pghome2010@gmail.com

Abstract
This study was undertaken to assess the efficiency of macrophyte plants in removing heavy metal in municipal wastewater using laboratory scale quarry dust vertical constructed subsurface wetlands. Plants used were *Typha latifolia, Phragmites australis* and *Polygonam spp*. The control treatment was not vegetated. The parameters evaluated were the concentration of lead, cadmium and zinc in the influent and effluent sewage after different retention periods in the wetland. At the end of experiment the macrophytes were harvested and the concentration of the heavy metals in shoots and roots determined. *Polygonam spp.* absorbed highest amounts of Zinc while *Phragmites australis* absorbed the highest amount of lead and cadmium. The roots had a higher concentration of the heavy metals than the shoots. Planted beds differed in the removal rates of the heavy metals which were found to be dependent on the plant species. The percentage removal of the heavy metals from the raw sewage by the vegetated system was 87%, 83% and 84% for lead, cadmium and zinc respectively after a retention period of 8 days. The control surprisingly showed a percentage removal in excess of 60%, indicating that the removal of heavy metals was mainly accomplished by the quarry dust medium. The concentrations of the three heavy metals in the effluent sewage were all below the maximum allowable concentrations for discharge into the environment. The constructed wetlands were therefore effective in reducing the heavy metals concentrations from the raw sewage to tolerable levels.

Key words: constructed wetlands, wastewater, macrophytes, heavy metals, quarry dust

1.0 Introduction

Among the major challenges facing developing countries is the need to ensure on-going provision of the basic human service of sanitation. The replications of centralized, highly engineered human waste management systems, resultant of sanitary reforms of the 19th century have not been successful in many developing countries (Rose, 1999). This is largely due to lack of resources to construct and maintain such treatment facilities. The solution to this scenario requires innovative and sustainable approaches that are appropriate for protecting public health, recovering nutrient resources and protecting water resources from pollution.

What is becoming relevant and appropriate are the alternative low cost and effective wastewater treatment systems like the constructed wetland, which also promotes the recovery and reuse of wastewater resources. This way, wastewater treatment is transformed from a disposal-based linear systems (which is expensive in the long run) to a recovery based closed-loop system that promotes conservation of water and nutrient resources and contributes to improved public health (Edward and Martin, 1991; Rose, 1999).

Alternative technologies to conventional wastewater management have been found to be environmentally sound and economically viable approach to waste water management. Constructed wetlands for example have contributed to providing low cost sanitation in the developed temperate countries. Constructed wetlands have been found to have lower construction and maintenance costs and require low skilled labor for operation when compared to the conventional treatment systems. A limited database supports the capability of the subsurface flow wetland process for effective removal of metals and other priority pollutants (Kovacic *et al*., 2006; Reed, 2000; Reed *et al*., 1987). It is thus important to establish through continued experimentation, the utility of constructed wetlands in the removal of heavy metals.

There are two types of constructed wetlands: vegetated sub-surface flow and free surface flow. Free water surface (FWS) constructed wetlands closely resemble natural wetlands in appearance and function, with a combination of open-water areas, emergent vegetation, varying water depths, and other typical wetland features. A typical FWS constructed wetland consists of several components that may be modified among various applications but retain essentially the same features. These components include berms to enclose the treatment cells, inlet structures that regulate and distribute influent wastewater evenly for optimum treatment, various combinations of open-water areas and fully vegetated surface areas, and outlet structures that complement the even distribution provided by inlet structures and allow adjustment of water levels within the treatment cell. Shape, size, and complexity of design often are functions of site characteristics rather than preconceived design criteria

Subsurface flow (SF) constructed wetlands first emerged as a wastewater treatment technology in western Europe based on research by Seidel (1996) commencing in the 1960's, and by Kickuth (1977) in the late 1970's and early 1980's. Early developmental work in the United States commenced in the early 1980's with the research of Wolverton *et al.,* (1983) and Gersberg *et al.,* (1985)

The SF concept developed by Seidel included a series of beds composed of sand or gravel supporting emergent aquatic vegetation such as cattails(*typha*), bulrush(*scirpus*), and reeds(*phragmites*), with *phragmites* being the most commonly used. In the majority of cases, the flow path was vertical through each cell to an underlain and then onto the next cell. Excellent performance for removal of BOD_5, TSS, nitrogen, phosphorous, and more complex organics was claimed. Pilot studies of the concept in the United States were marginally successful, and it has not been utilized in recent years.

Kickuth (1977) proposed the use of cohesive soils instead of sand or gravel; the vegetation of preference was *phragmites* and the design flow path was horizontal through the soil media. Kickuth's theory suggested that the growth, development and death of the plant roots and rhizomes would open up flow channels, to a depth of about 0.6 m in the cohesive soil, so that the hydraulic conductivity of a clay-like soil would gradually be converted to the equivalent of a sandy soil. This would permit flow through the media at reasonable rates and would also take advantage of the adsorptive capacity of the soil for phosphorus and other materials. Very effective removal of BOD_5, TSS, nitrogen, phosphorus, and more complex organics was claimed. As a result, by 1990 about 500 of these "reed bed" or "root zone" systems have been constructed in Germany, Denmark, Austria, and Switzerland. The types of systems in operation include on-site single family units as well as larger systems treating municipal and industrial wastewaters. Many of the early systems were designed with a criterion of 2.2 m^2 of bed surface area per population equivalent (PE) (Boon, 1985). A PE in European terms is equivalent to the organic loading from one person, or approximately 0.04 kg/d BOD_5 in typical primary effluent. That is equal to a surface organic loading of about 180 kg/ha/d. The more recently constructed systems in Europe (European design and operation, 1990) have been designed for 5 to 10 m^2/PE (40-80kg/ha/d). The hydraulic loading at 5 m^2/PE(at an assumed 0.2m^3/d/PE) would be about 4 cm/d, which, in a commonly used term in the U.S., is equivalent to 23 acres/mgd of design flow, and would provide a hydraulic residence time (HRT) of about six days. For comparison, FWS wetlands in Europe are typically designed at 10 m^2/PE, which results in a surface area about twice that required for the SF type (Brix *et al*., 1992).

Two experiments were therefore conducted to evaluate capability of constructed wetlands in quarry dust medium planted with reeds (*Phragmites australis*), cattails (*Typha latifolia*) and smart water weed (*Poligonam spp*.) in removing lead, cadmium and zinc from raw sewage.

2.0 Methodology

Twelve normal washing basins were modified so as to be used in the experiment. The basins were fitted with a valve socket, plugged from inside, a few centimeters from the bottom and steel cap was used to close the socket. Quarry dust in the form of ¼" gravel was used as the filter media. The dust was placed in the basins to a depth of 5 cm. The first experiment tested cattails (*Typha latifolia*) smart water weed (*Poligonam spp*.) and as the wetland plants, while the second experiment was run with reeds (*Phragmites australis*) as the test wetland plant. The plants were planted in the basins in three replicates with each model having six plants. Three controls (where no plants planted) for the experiment were set up (Figure 1).

Figure 1: Experimental setup during the first experiment: reeds, cattails, smart weeds and control

The plants were then fed with normal water to stabilize the root systems of the plants. This was done for a period of 4 weeks. After stabilizing the normal water was replaced with raw effluent from the secondary stabilization pond of Thika sewerage treatment plant. The whole setup was placed under a roof to avoid dilution of influent by rain water and to avoid excess evaporation.

During the first experiment, effluent from each wet land was collected from each basin after 2,4,6 and 8 days and the concentration of lead (PB, cadmium (CD) and zinc determined using the atmospheric absorption spectrophotometer (AAS) machine following the normal process. In addition plants were also harvested before and after use in the constructed wetlands, dried in an oven, incinerated in a furnace and the ash tested for Pb, Cd and Zn concentration using the AAS machine following the normal procedures.

During the second experiment, effluent from the wetlands was collected from each basin after 2, 4, 6 and 8 days and the concentration of lead (Pb), cadmium (Cd) and Zinc (Zn) determined using the Atomic Absorption Spectrophotometer (AAS) machine following the normal procedures. At the time of sampling the plants had fully established as shown in Figure 2.

Figure 2: Fully established reeds during the second experiment

3.0 Results and Discussion

Experiment 1

The concentration of the heavy metals in the raw sewage and river water at the beginning of the two sampling cycles is shown in Table 1. The concentration differed between the two cycles of research with a higher concentration of Pb and Cd being higher in the first cycle than the final cycle of sampling. This can be attributed to higher industrial activities at the first cycle than the final period. The results from river effluents for the two cycles differ with a higher concentration in the first cycle. Zinc concentration in the raw effluents registered a higher concentration in the final cycle than in the first cycle but the river effluent in the final cycle showed a low concentration of the same than for the first.

Experiment 2

Table 5 shows lead concentration in raw sewage and in the effluent from the constructed wetlands after different retention periods. The table indicates increased Pb removal with the retention time. After 8 days retention, 87.7% of the lead in the original raw sewage had been removed. Though the final effluent concentration was higher that NEMA recommendations of 0.01 mg/L, it was however lower than the current effluent quality from the Thika treatment plant which stands at 0.26 mg/L.

Table 5: Lead (Pb) concentration in the raw and effluent sewage after different retention periods and the corresponding % removal

Retention period (days)	Concentration (mg/l) wetland effluent	Maximum allowable value (mg/l)	Raw sewage (mg/l)	**%** removal by wetland
2	0.56	0.01	0.73	23.3
4	0.19	0.01	0.73	74.0
6	0.18	0.01	0.73	75.3
8	0.09	0.01	0.73	87.7

The Cadmium concentration in the raw sewage and after retentions periods of 2,4,6 and 8 days in the wetlands is presented in Table 6. The Cd concentration was marginally above the NEMA maximum recommended levels. The % removal increased with retention period reaching 83.3% after 8 days. Even for a retention period of 2 days, the effluent from the constructed wetlands was below the maximum level set by NEMA of 0.010 mg/L. The Cd concentration in the effluent from Thika wastewater treatment plant at the time of sampling was 0.011 mg/L indicating minimal removal by the plant.

Table 6: Cadmium (Cd) concentration in the raw and effluent sewage after different retention periods and the corresponding % removal

Retention period (days)	Concentration (mg/l) wetland effluent	Maximum allowable value (mg/l)	Raw sewage (mg/l)	% removal by wetland
2	0.0066	0.01	0.0113	41.6
4	0.0044	0.01	0.0113	61.1
6	0.0025	0.01	0.0113	77.9
8	0.0019	0.01	0.0113	83.2

In the case of Zinc, the removal % by the constructed wetlands was generally lower than for Pb and Cd (Table 7). After 8 days retention period, the % removal was only 70.4. This removal rate was much lower

than Gersberg et al. (1985) obtained in the Santee research (USA). They obtained a 97% removal after 5.5 days retention. The low retention our experiment could have been caused the small size of the wetlands. However, the Zn concentration even in the raw sewage was lower than the maximum level recommended by NEMA of 0.5 mg/L. Zinc concentration in the effluent is therefore not a serious concern as of now.

Table 7: Zinc (Zn) concentration in the raw and effluent sewage after different retention periods and the corresponding % removal

Sampling interval(days)	Concentration (mg/l) wetland effluent	Max allowable value (mg/l)	Raw sewage (mg/l)	**%**removal by wetland
2	0.015	0.5	0.027	44.4
4	0.013	0.5	0.027	51.9
6	0.011	0.5	0.027	59.3
8	0.008	0.5	0.027	70.4

Table 1: Heavy metal concentration (mg/L) of the raw sewage from Thika and in the river water

	Lead1st cycle	Lead final cycle	Cadmium 1st cycle	Cadmium final cycle	Zinc 1st cycle	Zinc final cycle
Raw sewage	1.0825	0.1183	0.7561	0.1250	0.7920	0.9944
River	0.4012	0.0189	0.2661	0.0152	0.3740	0.0665

Table 2 shows the concentration of the heavy metals in various macrophytes that were used in the wetland before their establishment and their results after harvest. The initial concentrations of the heavy metals differed between the plants as they were collected from different sites. The after harvest results indicate absorption of the heavy metals by the three plant species. The concentrations increased by as 95 times for lead in *Polygonam spp*., 31 times for Cadmium in *Phragmites australis* and over 250 times for Zinc in *Polygonam spp*. This indicates high ability by these plants to uptake the heavy metals. The uptake is however dependent on the plant species.

Table 2: Zinc, Cadmium and Lead concentrations (mg/L) before and after their use in the constructed wetland

Macrophyte	Lead		Cadmium		Zinc	
	Before sampling	After sampling	Before sampling	After sampling	Before sampling	After sampling
Phragmites australis	0.0007	0.0096	0.0003	0.0094	0.0039	0.3098
Typha latifolia	0.0001	0.0079	0.0018	0.0089	0.0068	0.2553
Polygonam spp.	0.0006	0.0057	0.0005	0.0073	0.0021	0.5292

The difference in the removal rates in the macrophytes in the wetlands could be due to difference in the affinities for the lead by the macrophytes and probably the different root densities of the different plants (Table 3).

Table 3: Levels of Pb, Cd and Zn in mg/L in the roots of the macrophytes used in the wetland

	Phragmites australis			*Typha latifolia*			*Polygonam spp.*		
	Pb	Cd	Zn	Pb	Cd	Zn	Pb	Cd	Zn
Plant roots	0.0096	0.0094	0.3098	0.0079	0.0089	0.2553	0.0057	0.0073	0.5292

Table 4 summarizes the performance of the wetlands planted with the three macrophytes in terms of effluent quality during the first and second cycle. The three macrophytes showed similar trends in the % removal of lead with values of 90.3, 89.4 and 90.8 for *Typha latifolia*, *Polygonam spp*. and *Phragmites australis* respectively during the second cycle. The corresponding values for Cadmium were 91, 89, and 92 respectively. The % removal of Zinc was however higher at 97.5, 978 and 97.5 for *Typha latifolia*, *Polygonam spp*. and *Phragmites australis* respectively. These high removals indicate the possible utility of constructed wetlands as alternative wastewater treatment systems. The control treatment (without plants) is seen to exhibit a relatively high % removal of the heavy metals with 67, 68 and 63% removal for lead, cadmium and zinc respectively. This indicates that the plant removed on average 25% of the heavy metals. The role of the filter media is therefore very significant.

Table 4: The performance of the wetlands planted with different macrophytes during the two sampling cycles

Sample	*Typha latifolia*		*polygonam spp*		*phragmites australis*		Max. allow.	%removal-control
	cycle 1	cycle 2	cycle 1	cycle 2	cycle 1	cycle 2		
Control	0.3548	0.0152						67.23
Lead :1st sampling.	0.2349	0.011	0.3111	0.0126	0.259	0.0111		
Lead :2nd sampling.	0.2268	0.012	0.2546	0.0124	0.2308	0.0106	**0.01**	
Average concentration.	0.23085	0.0115	0.2828	0.0125	0.2449	0.0108		
Raw sewage concentration.	1.0825	0.1183	1.0825	0.1183	1.0825	0.1183		
% rate of removal	78.7	90.3	73.9	89.4	77.4	90.8		
Control	0.2041	0.0169						68.25
Cadmium	0.2255	0.011	0.171	0.014	0.2102	0.0099	**0.01**	

:1st sampling.		4	5							
Cadmium :2nd sampling.	0.1147	0.0111	0.1331	0.0131	0.0986	0.0099				
Average concentration.	0.1701	0.0113	0.1523	0.0136	0.1544	0.0099				
Raw sewage concentration.	0.7561	0.125	0.7561	0.125	0.7561	0.125				
% rate of removal	77.51	91	79.86	89.16	79.58	92.08				
Control	0.2917	0.1118								63.17
Zinc : 1st sampling.	0.2631	0.0233	0.2505	0.0197	0.2832	0.0265				
Zinc :2nd sampling.	0.2296	0.0269	0.18	0.0199	0.201	0.0244	**0.5**			
Average concentration.	0.24635	0.0251	0.2153	0.0198	0.2421	0.0255				
Raw sewage concentration.	0.792	0.9944	0.792	0.9944	0.792	0.9944				
% rate of removal	68.9	97.5	72.82	98	69.43	97.45				

4.0 Conclusions

The results of this study have shown that wetlands are suitable alternatives for the treatment of wastewater. The rate of removal varied according to the plant species in the wetland. *Typha latifolia* and *Phragmites australis* were found to have high removal rates for lead. *Typha latifolia* had removal rates >78% during the first cycle and *Phragmites australis* had >90% removal rate during the final cycle. The combination of reed and *Typha latifolia* is considered to have a better removal and affinity for lead.

Phragmites australis bed was found to remove high amounts of the cadmium metal. The rate of removal was found to be > 72% and 86% for the first and second sampling periods of the first cycle. In the final cycle it was found to be 92.08% for both the sampling periods. Reed is then concluded that it is better alternative for the removal of cadmium, (Table 5 and 6).

Polygonam spp. had a higher removal rate for Zinc metal with removal rates of 68.37% and 77.27% for the 1st and 2nd sampling periods of the first cycle. The final cycle rates for Polygonam spp. were 98.02% and 98% for 1st and 2nd sampling periods respectively. Therefore *Polygonam spp.* is concluded to have better removal rates for zinc metal and should be used in the removal of the Zinc in wastewater.

Therefore, *Phragmites australis, Typha latifolia and Polygonam spp.* have the potential in remediating sites that contain high concentration of Pb, Cd and Zn. The filter media was found to take a major part in

the removal of the heavy metals when compared to macrophytes which generally had lesser uptakes of heavy metals. This indicates that the filter media has a significant role in the removal of the heavy metals in wastewater. There is difference between the uptakes of the metal ions by the macrophytes. The plant roots play a major role in the uptake as compared to the shoot uptake as higher concentration is found to be in the roots.

Bearing in mind that the filter media acts as a sink for heavy metals, it would suffice that there would be exhaustion of the exchange sites, and thus reduced utility with time. However, they can be used in polishing of treated waste water from conventional treatment plants, or as stand-alone plant.

REFERENCES

Bista, K. R. and Khatiwada, N. R. Department of Water Supply and Sewerage (DWSS), Panipokhari, Kathmandu, Nepal.

Biosystems Engineering (2005) 92 (4), 535-544. http://www.sciencedirect.com

Boon, A. G. (1985). Report of a Visit by Members and Staff of WRC TO Germany to Investigate the Root Zone Method for Treatment of Wastewaters. Water Research Centre Stevenage, England.

Breen, P. F. and Chick. A. J. (1995). Root zone dynamics in constructed wetlands receiving wastewater: a comparison of vertical and horizontal flow systems. *Water Science & Technology*, **32**(3), pp 281-290.

Burge, W. D., Colacicco, D. and cramer, W. N. (1981). Criteria for Achieving Poathogen Destruction during Cornposting. *JWPCF,* **53**, pp 1683.

California Storm water BMP Handbook, 2003, Constructed Wetland.

Carpenter S. R. et al (1998). Nonpoint pollution of surface waters with phosphorus and nitrogen. Ecol. Appl. 8: 559-568. Constructed Wetlands for Metals Removal", Midwest Hazardous Substance Research Center, Purdue, July 2003, 3 pp.

Cooper P. F., Job G. D., Green M. B., Shutes R. B. E. (1996). Reed bed and constructed wetlands for wastewater treatment, WRC Publication, Mesdmenham, Marlow, UK, pp. 1-6.

Coulibaly et al. *African Journal of Biotechnology,* Vol. **7**(15), 4 August, 2008. http://www.academicjournals.org/AJB

Fitch, M. W., and Burken, J. G., "Midwest Hazardous Substance Research Center Brief #1:

Gearheart, R. A. (1983). Final Report City of Arcata Marsh Pilot Project. City of Arcata Department of Public works. Arcata, CA.

Gearheart, R. A., and Finney, B. (1999). "The Use of Free Surface Constructed Wetlands as An Alternative Process Treatment Train to Meet Unrestricted Water Reclamation Standards",*Wat. Sci. Tech.,* Vol. **40** (4-5), pp. 375-382.

George, D.B. et al. (2000). Development of guidelines and design equations for subsurface flow constructed wetlands treating municipal wastewater. USEPA, Office of Research and Development, Cincinnati, OH.

Gersberg, R. M., Brenner, R., Lyon, S. F. and Elkins, B. V. (1987). Survival of Bacterial and Viruses in Municipal Wastewaters Applied to Artificial Wetlands. **In**: Aquatic Plants for Water Treatment and Resource Recovery. Magnolia Publishing, Inc. Orlando, FL. Pp. 237-245.

Gupta, A. K. and Sinha, S. (2007). Phytoremediation capacity of the plants growing on tannery sludge dumping sites. *Bioresource Technology*, **98**, pp 1788-1794.

Halvelaar, A. H., and Hogeboom, W. M. (1984). A Method for the Enumenation of Male- Specific Bacteriophages in Sewage. *J. Appl. Bacterria*, **56**, pp 439-447.

Hammer, D. A. (ed.) (1994). Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers. Chelsea, MI.

IWA, (2000). Application of the technology. In Constructed Wetlands for Water Pollution Control: Process, performance, Design and Operation. Science and Technical Report No. 8, International Water Association: London. pp. 23-39.

J. Aquat. Plant Manage. 42: 60-68 2004 Heavy Metal Phytoremediation by Water Hyacinth at Constructed Wetlands in Taiwan *(*SHAO-WEI LIAO AND WEN-LIAN CHANG).

J. W. Day Jr. et al. / Ocean & Coastal Management 47 (2004).

Jankiewicz, L. (1972). Survival of Ascaris Eggs on Soils Irrigated with communal Sewage, Zesz, nauk, A.R. –Wroc. Melioracje, XV. No. 90, p.61-66. **In**: Critical Review and Asessment of the Polish Literature on Sewage Irrigation, Institute of Meteorology and Water Management Wroclaw Poland), Technical Interim Report No.1 on Project JB-5-532-24, Dec. 1977. Abstract No. 193.

Kadlec, R. H., Knight R. L. (1996). Treatment wetlands. Lewis Publishers, Boca Raton, FL.
Kadlec, R. H. (2000). The Inadequacy of First-Order Treatment Wetland Models. *Ecological Engineering,* vol. **15**, pp 105-109.

Kickuth, R. (1977). Degradation and Incorporation of Nutrients from Rural Wastewaters by plants rhizosphere under liminic conditions. Utilization of manure by land spreading, Comm of the Europe Communitite, EUR 5672e, London.

Liehr, R. K. et al. (2000). Constructed wetlands treatment of high nitrogen landfill leachate. Project Number 94-IRM-U, Water Environment Research Foundation, Alexandria, VA.

Liu H, and Logan B. E. (2004). Electricity generation using an air-cathode single chamber microbial fuel cell in the presence and absence of a proton exchange membrane, *Environ Sci. Technol.*, **38**(14), pp 4040-4046.

Mark Fitch, Joel Burken, Constructed Wetlands for Metals Removal, University of Missouri-Rolla (October 1, 2002 – September 30, 2003).

Middlebrooks, E. J. (1980). Aquatic Plant Processes Assesment. In: Aquaculture Systems for Wastewater Treatment: An Engineering Assessment. US Environmental Protection Agency, EPA 430/9-80-006, NTIS No.PB 81-156705.

Nancy V. Halverson, (2004). Review of Constructed Subsurface Flow vs. Surface Flow Wetlands.

Rajendra G. Kurup, an experimental research on application of sub surface constructed wetland for meat processing industry effluent treatment and nutrient removal, 2007.

Rash, J. K. and Liehr, S. K. (1999). Flow pattern analysis of constructed wetlands treating landfill leachate, *Water Science & Technology*, **40**(3), pp 309-315.

Reed, S. C., Middlebrooks, E. J. and Crites, R. W. (1987). Natural Systems for Wastewater Management and Treatment. McGraw-Hill Book Co., New York, NY

Rose, G. D. (1999). "Community-based Technologies for Domestic wastewater Treatment and Reuse: options for urban agriculture" In Cities feeding People, CFP Report Series, Report 2.

Sim, C. H. (003). The use of constructed wetlands for wastewater treatment. Wetlands International - Malaysia Office.

Smith V. H., et al (1999). Eutrophication: Impacts of excess nutrients on freshwater, marine, and terrestrial ecosystems. *Environmental Pollution*, **100**, pp 179-196.

T. Manjios, et al, (2002). Environmental technology volume 23 pp767-774 selper limited United States Environmental Protection Agency Manual, design manual 2000, Office of Research and Development, Constructed Wetlands Treatment of Municipal Wastewaters United States Environmental Protection Agency, 1993, Constructed Wetlands for Wastewater Treatment and Wildlife Habitat.

United States Environmental Protection Agency, (1993). Subsurface Flow Constructed Wetlands for Wastewater Treatment- A Technology Assessment.

Vardayan, L. G. and Ingole, B. S. (2006). Studies on heavy metal accumulation in aquatic macrophytes from Sevan (Armenia) and Carambolin (India) lake systems. *Environmental International*, **32**, pp 208-218.

WHO (2000). Global water supply and sanitation assessment, 2000 report. World Health Organization, Geneva, Switzerland.

WHO (2003). Guidelines for safe recreational water environments. Volume 1. Coastal and freshwaters. World Health Organization, Geneva, Switzerland.

Yoon, Chun G., Kwun, Soon G., Ham, Jong H., 2001. Feasibility Study of a Constructed Wetland for Sewage Treatment in a Korean Rural Community. *Journal Environmental Science and Health,* A **36** (7), pp 1101-1112.

Young, T.C., A.G. Collins, and T.L. Theis. 2000. Subsurface flow wetland for wastewater treatment at Minoa, NY. Report to NYSERDA and USEPA, Clarkson University, NY

Kovacic, D. A., Twait, R. M., Wallace, M. P. and Bowling, J. M. (2006). Use of created wetlands to improve water quality in the Midwest - Lake Bloomington case study. *Eco. Eng.,* **28**(3), pp 258-270.

Reed, S. C. (2000). Land treatment systems for municipal and industrial wastes. McGraw-Hill, USA.

INVESTIGATING REMOVAL OF PESTICIDES FROM WATER BY NANOFILTRATION MEMBRANE TECHNOLOGY

N. J. Riungu[1], M. Hesampour[2], A. Pihlajamaki[3], M. Manttari[4], H. Sirén[5], P. G. Home[6], G. M. Ndegwa[7]
[1,6,7]Department of Biomechanical and Environmental Engineering, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[2,3,4,5]Department of Chemical Technology, Lappeenranta University of Technology, Finland

Abstract
Agricultural activities form the backborne of Kenya´s economy. Inorder to control crop losses, pesticides are used and in the recent past, more of the pesticides have been used to increase production. However, the effect of pesticides on the environment is very complex as undesirable transfers occur continually among different environmental sections. This eventually leads to contamination of drinking water sources such as rivers and lakes located near active agriculture areas, including flower farms around Lake Naivasha where poisoning of lake water by pesticides caused fish deaths. The aim of this paper was to investigate application of nanofiltration membrane technology in the removal of pesticides from water. A pesticide, atrazine was selected for the study due to its extensive use in controlling weeds and the adverse environmental effects associated with it. Membrane filtration was used using a laboratory scale crossflow filtration units that operated in total recycle mode to ensure even concentration of atrazine in the feed solution to seperate atrazine form water. Concentration of atrazine in aqueous solution was analyzed using high performance liquid chromatography (HPLC). Retention of atrazine by four nanofiltration membranes i. e. NF90, NTR7250, and NF270 was investigated. The effect of feed solution pH, concentration and feed pressure were investigated, as was the effect of humic substances and titanium dioxide catalyst on retention by membranes. pH and feed pressure showed influence on retention of atrazine while initial feed concentration had little influence. The presence of HA led to improved atrazine rejection efficiency but led to flux decline on all membrane tested while TiO_2 led to high rejection efficiency and low flux decline. Of all four membranes, NF90 showed the best performance in retention of atrazine in water while NTR7250 showed the least. This indicated that with proper membrane selection, its possible to treat water contaminated with pesticides to acceptable levels.

Key words: Pesticides, nanofiltration, membranes, retention

1.0 Introduction

Agricultural activities are the main food source for the world´s population. Pesticides are used inorder to control crop losses and in the past years, more and more pesticides have been used to increase production. However, the effect of pesticides on the environment is very complex as undesirable effects occur to both human, animals and the aquatic environment. They lead to contamination of drinking water sources such as rivers, lakes and groundwater.

In recent years various international and local regulations have become stricter concerning the amounts of pollutants in wastewaters and the quality of the treated effluents discharged into the aquatic environment. This is mainly because the pollutants are known or suspected to cause harmful ecological effects. Widespread concerns are being raised due to the increasing number of cases, when such contaminants are detected in surface water bodies and due to their potential to affect the development, reproduction and health of wildlife, livestock and even humans. Most contaminants found in aquatic environment mainly comprice of organic compounds. Organic matter found in water spans a wide spectrum, with molecular weights ranging from several thousands to less than 100 g/mol.

Most compounds on the upper end of this spectrum are of natural origin, and they are commonly known as natural organic matter (NOM). Trace organics are generally located at the lower end of the organic compound spectrum. The trace organics include pesticides, trihalomethanes (THMs), polychlorinated biphenols (PCBs) and polyaromatic hydrocarbons (PAHs) and are commonly reffered as persistent polar pollutants (PPPs) due to their persistence in the environment. PPPs have been identified as an increasing problem in our drinking water supplies. Such substances can enter the waters supply from various sources and are not effectively removed by conventional water treatment processes.

Pesticides have been classified as PPPs due to their resistance to natural degradation processes, and hence their ability to remain in the environment for long periods of time. By their very nature, they are designed to be toxic and kill unwanted organisms, but can attack non-target organisms and as a result cause serious environmental damage. Due to the extensive use of pesticides in industry and agriculture, many water sources are contaminated with pesticides, especially, wastewater from agriculture farms and pesticides formulating or manufacturing plants (Shaalan *et al.,*2007).

Atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) has been a widely used herbicide to control certain annual broadleaf weeds and grasses throughout the world over the last 50 years. It has been found in groundwater at concentrations exceeding the ground and drinking water limit of 0.1 μg L^{-1} of the European Union (Spliid and Koppen, 1998). It is less expensive and persists longer in the soil than alternative herbicides, with a lifetime of days or even years in the environment.

Conventional water treatment processes, specifically coagulation–flocculation, sedimentation and conventional filtration, are not very effective in removing pesticides from drinking water (Plakas *et al.,* 2006). Traditional plants are far from efficient and offer removal levels that rarely exceed 10–20% for atrazine and 40% for simazine (Zhang *et al.,* 2004). Disinfection and water softening, however, may lead to pesticide transformation and formation of disinfection byproducts (USEPA, 2001). Removal of pesticides for the production of drinking water can be conducted by activated carbon filtration (Herrera *et al.,* 2006, Acero *et al*., 2009). It is an expensive procedure that requires frequent regeneration. This is because organic micropollutants, such as pesticides, may be present at the μg/L level. NOM concentrations may be 10,000 times higher, hence the adsorption columns have to be regenerated rapidly, because the column capacity is mainly used for NOM adsorption instead of pesticides adsorption (Bruggen *et al*., 2003). In parallel, some chemical treatments have been applied for the

reclamation and reuse of different wastewaters and surface waters containing pesticides, by using clean-up chemicals and techniques such as several oxidants like ozone and hydrogen peroxide, UV radiation, and their combinations (advanced oxidation processes) (Ormad *et al.,* 2008, Acero *et al.,* 2009). The reaction may not be very selective for degradation, as is the case in oxidation process, where ozone is known to produce a variety of aldehydes (Nghiem, 2005).

Over the past few years, nanofiltration (NF) membranes have been studied as potentially useful means of pesticide removal considering the fact that the molecular weights (MWt) of most pesticides are more than 200 Da (Kamrin *et al*., 1997, Plakas *et al*., 2006). Nanofiltration has been successfully applied in drinking water treatment plant in Mery-sur-Oise, France (Cyna *et al*., 2002) and Heemskerk (Hofman et al.,1997) Holland as well as Saffron Walden in England. However, there is still a long list of pesticides in guidelines for drinking water by World Health Organization (WHO, 2004) but there is lack of adequate data for their effective separation using membranes. Therefore, there is still room for investigation of the feasibility of using membrane technology to completely remove atrazine from water.

The main objective of this study was to investigate the removal of atrazine by NF membranes. The effect of operating parameters of the feed solution on the rejection efficiency for atrazine; pH, concentration and feed pressure were investigated. The effect of humic substances and titaniumd catalyst on the rejection efficiency and operation of the membranes was of concern too.

2.0 Materials and Methods

2.1. Experimental Procedure

The experiment was conducted to investigate the retention of atrazine by three NF membranes. The effect of solution pH on retention of atrazine by the membranes was assessed. Three different pH values for the feed solution were used namely; pH 4, pH 7 and pH 9. Furthermore, the effect of humic acid and titanium dioxide on the membrane performance was studied.

2.2 Membranes

Previous researches have shown that membrane processes, such as reverse osmosis (RO) and nanofiltration (NF) are considered promising candidates for the removal of low molar mass organic compounds of environmental concern, like pesticides (Plakas and Kalabelas, 2009, Shaalan *et al*., 2007). The molar masses of most pesticides and herbicides are in the range of 200-400 g/mol, which is the normal cut-off range for most NF membranes. Three NF membranes were investigated in this study. The characteristics of the membrane used are shown in Table 1.

Table 1: Characteristics of membranes used in the study

	NF270	NF90	NTR7250
Manufacturer	Dow (Filmtec)	Dow (Filmtec)	Nitto Denko, Japan
MWCO	200[a]	200[a]	300-450[b]
Zeta potential (mV)	-21.6[c]	-24.9[c]	-6[d]
Contact angle	28±2[e]	62±2[e]	Na[f]
Membrane pore size (nm)	0.71±0.14[g]	0.55±0.13[g]	0.65[a]
NaCl retention (%)	66.4[h]	99.5[h]	50[i]
Membrane	Polyamide[j]	Polyamide[j]	Polyvinyl alcohol[k]

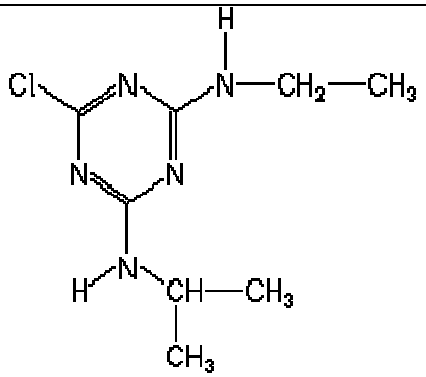
material (skin)			
pH range	3-10[j]	3-10[j]	2-9[k]
Maximum temperature	45[j]	45[j]	40[k]

a- As stated by manufacturer
b- Verliefde, *et al*, 2005
c- Plakas and Kabelas, 2008; Measured atpH7 and 30_S/cmKCl solution (PAAREKA-Electro Kinetic Analyzer RV. 4.0).
d- Nymston *et al*., 1995; Measured at pH7 and salt solution used; 1.0 mM KCl, T= 25°C, p = 0-70 cm H20.
e- Plakas and Kabelas, 2008; Sessile drop contact angle measurements.
f- na (not available)

2.3 Herbicide

The herbicide atrazine which has had a significant share of the herbicide market and is detected with great frequency in drinking water sources, was selected for the experiments. The molecular structure and some physicochemical properties of the tested herbicide is presented in Table 2. The herbicide is hydrophobic (log *K*ow > 2), moderately soluble in water and therefore weakly polar compound (Plakas and Kalabelas, 2008).

Table 2: Properties of herbicide used in the study (W. S. S. A., 1994)

Chemical structure	
Molecular formula	$C_8H_{14}ClN_5$
Molar mass (g/mol)	215.69
Molecular size (nm)[a]	0.788
Log K_{ow}	2.68
Aqueous solubility (mg/L)	33

a- Bruggen et al., 1998

2.4 Solution Preparation

A standard stock solution of concentration 100 mg/L was prepared for atrazine in high-performance liquid chromatography (HPLC)-grade methanol and stored at 4 °C. The feed atrazine solutions at a level of 10 mg/L and 20 mg/L were prepared from stock solutions by diluting with pure water. The experiments were carried out with feed solutions at pH 4, pH 7, pH 10 and natural pH of atrazine solution which is pH 8.3.

The pH of the atrazine feed solution was adjusted to different pH by adding 1M NaOH or 37% (w/w) HCl (Fisher Scientific, Pittsburg, PA). The pH measurement was conducted using pH meter (Mettler Toledo Delta 320 pH Meter). Methanol was used for preparation of stock solution but the cosolvent effect was not considered in this paper.

Retention of 10 ppm atrazine solution was tested in presence of humic substances and TiO_2. Humic acid (HA) was used to simulate the effect of organic matter found in natural water on the atrazine retention. Since humic substances concentrations in natural waters usually fall in the range of 2–40 mg/L (Jones *et al*., 1998) the solution was prepared with ultra-pure water and with a concentration of 10 mg/L humic acid. The HA was obtained in powder form and used without further purification. Humic acid sodium salts was supplied by Sigma–Aldrich company. Titanium dioxide solution (10 ppm TiO_2, C380 from TIPE Company, China) had primary particle size of 6-8 nm.

2.5 Filtration Setup

The filtration was carried out in a laboratory scale cross-flow filtration unit that operated in total recycle mode where permeate and retentate were returned to the feed tank. A schematic presentation of the unit is shown in Figure 1 below. The model solution in the feed tank was pumped to flat sheet membrane module by a centrifugal pump. The unit consisted of three membrane modules arranged in parallel. The required pressure and flow velocity were achieved by controlling the power of the pump and the back pressure valve after the membrane module. The effective surface area of each membrane module was 10.4 cm^2. The temperature was maintained constant by re-circulating cold water in the jacket around the feed tank.

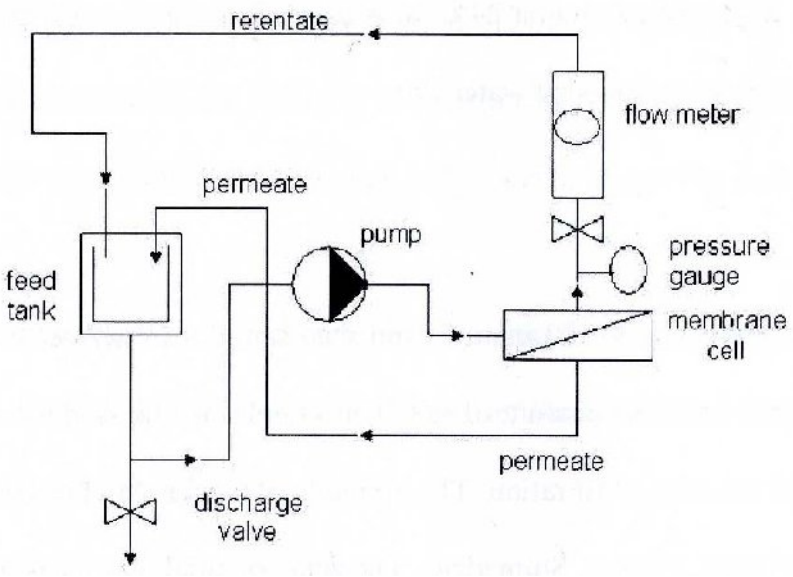


Figure 1: Schematic diagram of cross flow filtration unit

2.6 Filtration Procedure

The feed tank capacity 5 L was filled with the feed solution. Prior to commencement of experiment, the pure water flux was measured. The filtration experiments were carried out at pressures of 6 bar and 12 bar respectively and a velocity of 2.5 m/s and temperature of 25^{o}C.

The filtration protocol involved a sequence of the following steps

(i) First, the membrane was rinsed with tap water for several minutes and afterwards it was fitted in the module, then the membrane sample was pressurised with pure water under 15 bar for 4 hours to ensure that the removal of preservatives from the new membrane coupon was complete and that it was compacted (Plakas et al. 2008). Compaction is crucial in every membrane filtration protocol as it may change both the active layer and its support, thus affecting the flux and the rejection properties of the membrane. To eliminate this impact, membranes were subjected to a higher pressure (15 bar) than the operating pressure (12 bar, maximum for this study) to ensure flux stability during experiments (Schafer *et al*., 2005).

(ii) Measurement of the pure water flux at 6 bar, then stabilized water flux at different operating pressures was obtained and membrane permeability value (*L*p) was determined from the slope of flux against pressure graph.

(iii) Filtration of 10 ppm atrazine at 6 bar and 12 bar, each for 3.5 hours respectively at natural pH (8.3) of the solution.

(iv) Filtration of 20 ppm atriazine at 6 bar and 12 bar, each for 3.5 hours respectively at natural pH of the solution.

(v) Filtration of 10 ppm atrazine solution at pH of 4, 7 and 10 respectively each for a duration of 3.5 hours and pressure 12 bar.

(vi) Filtration of 10 ppm atrazine solution in presence of 10 mg/L TiO_2 catalyst and 10 mg/L HA solution respectively at a pressure of 12 bar.

After each experiment, the membranes were rinsed with pure water at same conditions as the filtration process and pure water flux measurements were made. Permeate from the bottom of the membrane modules was collected on 30 minute interval and its mass was measured. The cumulative mass was converted to cumulative permeate volume (*V*p), and the permeate flux (*J*w for pure water, or *J*v for the atrazine solutions) was obtained by means of Equation 1:

$$\text{w} = \frac{\Delta}{\Delta} \quad \text{.....(1)}$$

Where Δ is the accumulated permeate mass during the time difference Δ and *A* is the membrane area. At the same time, samples were collected for analysis of atrazine concentration by use of HPLC.

2.7 Analytical Method

The concentration of atrazine in feed and permeate was analysed using a HP 1050 high performance liquid chromatography (HPLC) by on-line coupled with a DAD detector and a ESI-MS by Agilent (Germany). Isocratic eluent: 20 mM ammonium hydroxide-methanol mixture (50:50, v/v). flow rate: 0.15 mL/min. Column: Luna 3u C18(2) 100A reversed phase (100 mm x 2.00 mm, 3 µm particles) by Phenomenex (Copenhagen, Denmark). Separation temperature was ambient (app. 27 ^{o}C). The samples were injected with auto-sampler. The volume of the sample in each injection was 2 l.

The effectiveness of a membrane is measured on how much of the feed material is retained during operation. This is termed as retention and is calculated using the following equation:

$$= 1 - — * 100 \quad \text{.....(2)}$$

where R is the observed retention, ***cf*** the concentration of the feed and ***cp*** the concentration of the permeate.

3.0 Results and Discussion

3.1 Influence of pH, Atrazine Concentration and Pressure on Retention

The retention performance of atrazine by NF90, NTR7250, NF270 membranes at different pressure, concentration and pH is presented in Figure 3.

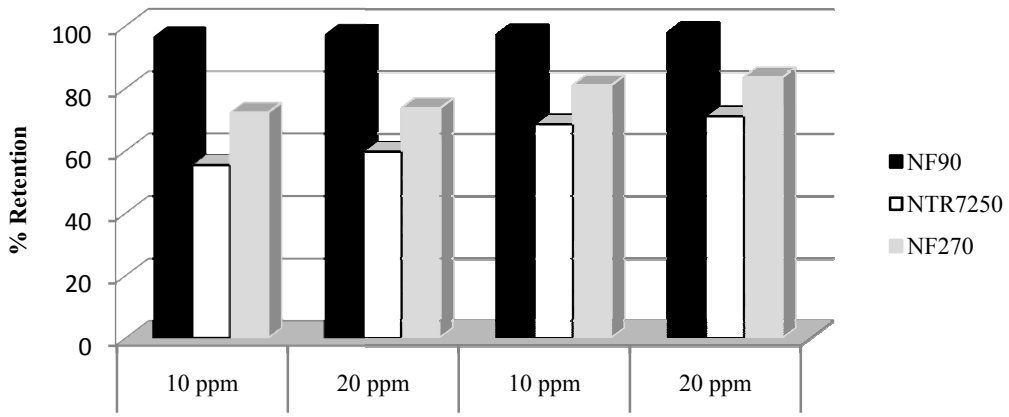


Figure 3: Membrane retention performance at a flow velocity of 2.5 m/s, Temp. 25°C and pH 8.3.

From these figures, it is obvious that the retention of atrazine tended to be better when the pressure was increased from 6 bar to 12 bar. It can be seen that NF90 produced the best retention for atrazine being more than 95% at the operating pressure and feed concentration tested. The performance of NF270 was the second highest of all three membranes tested while NTR7250 showed lower retention than NF270 when both were operated at the same pressure and feed concentration. Higher retention was observed at higher pressure due to the increased water flux that caused dilution of permeate from the membranes. Similar findings were reported by Armad *et al*., (2008) during filtration of dimethoate and atrazine using nanofiltration membranes at different pressures.

As Figure 3 shows the retention did not vary greatly regardless of the initial atrazine concentration. The retention results with atrazine solutions are in agreement with observations made by other researchers (Zhang *et al*., 2004, Plakas *et al*., 2009) in that herbicide concentration does not significantly affect their retention. In practical terms, the consequence of this result is that different stages of a nanofiltration plant have the same efficiency level so far as atrazine is concerned at very dilute concentration. The influence of the pH on the retention is shown in Figure 4.

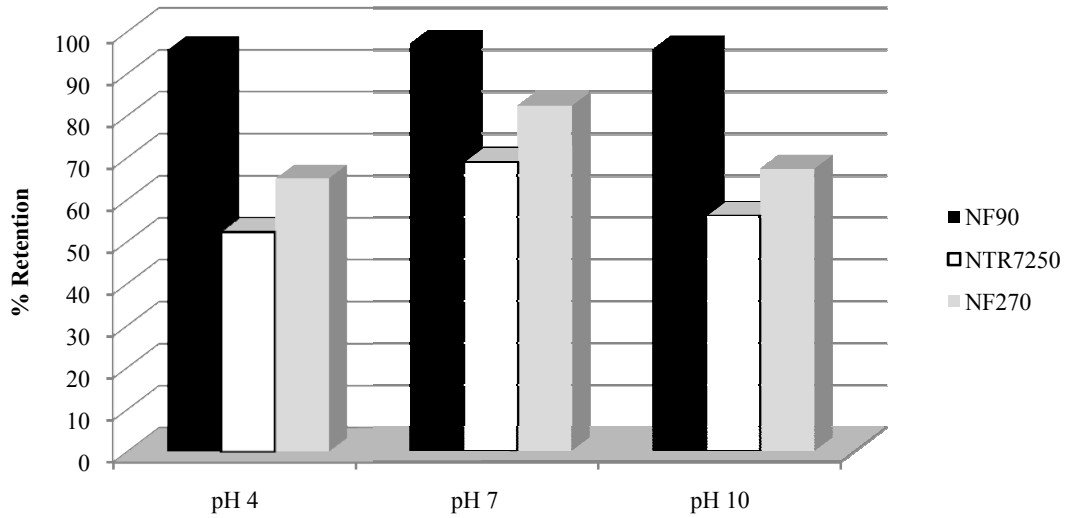


Figure 4: Membranes retention performance at various pH conditions; Temp. 25^{0}C, crossflow velocity 2.5 m/s, pressure of 12 bar for 10 ppm atrazine concentration

NF90 membrane showed almost consistent retention for all tested conditions while the NF270 and NTR7250 showed varying retention at different pH. The retention was the highest at pH 7;while at pHs 4 and 10, the retentions were consistently lower. This was caused by ion adsorption: at higher pH, OH^- ions can adsorb on membrane surface, resulting in an increase of the membrane charge. Polar components such as pesticides have a lower rejection when the membrane charge increases, because they are dipoles which can have a preferential orientation towards the membrane in the sense that the side of the dipole with a charge opposite to the membrane charge is the closest to the membrane. In this way, the preferential orientation results in an increased attraction, an increased permeation and thus a lower rejection. At lower pH, the same effect might occur with H^+ ions. The NF90 and NF270 have the same MWCO as seen on Table 1 but NF90 recorded the highest retention of over 95%. The MWCO is defined as the molecular weight of a solute that was rejected at 90 percent. NF90 was rather chemical-resistant as it showed somewhat consistent performance regardless of the solution's pH. There was only a drop of about 2% of retention performance for NF90 compared to the obvious increase or reduction of retention performance shown by the rest of the nanofiltration membranes tested. The NF90 and NF270 membranes are slightly different although with the same polyamide thin-film composite. NF270 has a very thin semi-aromatic piperazine-based polyamide active layer while NF90 consists of a fully aromatic polyamide active layer (Ngiem *et al.,* 2004) while NTR7250 is made of a combination of poly vinyl alcohol and piperazine trimesamide (Nyström *et al.,* 1995).

Puasa, (Puasa *et al*., 2006) reported that polyamide thin-film composite membranes have charge characteristics that influence the separation capabilities, which can be altered by the solution's pH and it was reported that the isoelectric point of polyamide membrane is generally between 4 and 5. According to Nyström et al., (Nyström *et al*., 1995) the isoelectric point of poly vinyl alcohol is between 3 and 4. The occurrence of an isoelectric point means that at lower pH than the isoelectric point, the membrane is positively charged and vice-versa. Hence, in the case of polymeric membranes, membrane surface charge is typically negative at high pH values, it decreases as the pH decreases and switches to positive values at low pH's (Bandini and Mazzoni, 2005).

3.1.2 Retention of Herbicides in Presence of Organic Matter and TiO_2

In the membrane separation experiments in which humic substances and TiO_2 were mixed together with herbicides, the final feed solutions were first prepared and placed in a foil-covered container (to prevent herbicide degradation by exposure to light) and stirred for 24 h, after which they were assumed to be at equilibrium - a protocol used by earlier researchers (Devitt *et al.,* 1998). The nanofiltration experiments show influence of humic acids acting on the retention of atrazine as shown in Figure 5.

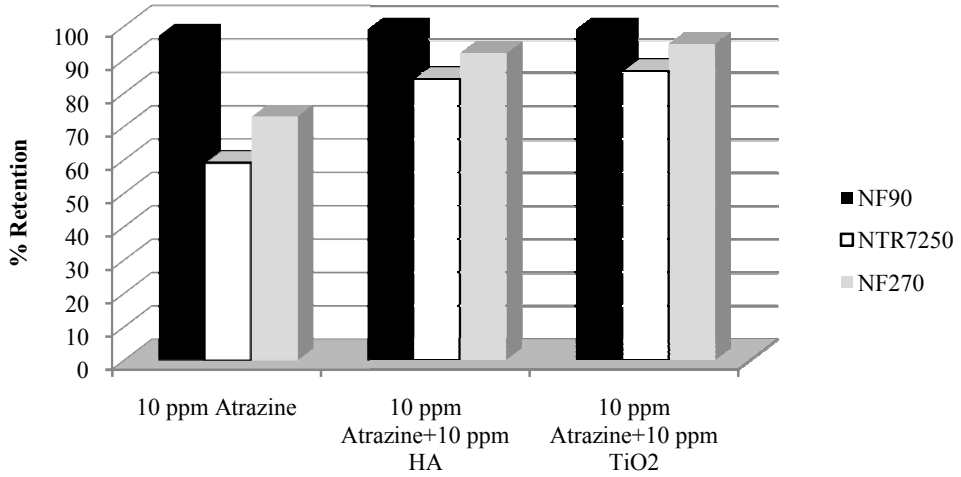


Figure 5: Membranes retention performance in presence of HA and TiO_2, s; pressure 12 bar, velocity 2.5 m/s , temperature 25^0C and pH 8.3

This is attributed to the formation of complexes between humic acids and atrazine, which enhance the rejection by steric exclusion. According to Chiou *et al*., (1986) hydrophobic humic substances of high molecular weight are not very soluble in water and display a stronger interaction with non-ionic complexes like atrazine. This interaction between herbicides and humic substances can be attributed to the large number of functional groups characterizing the structure of humic materials.

The effect of humic substances on atrazine adsorption and retention is in agreement with other studies; the explanation is that a low energy bond between humic substances and atrazine is established by physisorption which results in an increased steric exclusion of the humic substance-atrazine pseudocomplex (Kulikova *et al*., 2002, Plakas *et al.,* 2006). Moreover, the density of the complex negative charge increases due to the primary negative charge of humic substances, while the adsorbability of the complex on the surface of the membrane is enhanced due to the hydrophobic nature of humic acid.

The nanofiltration experiments in which TiO_2 was mixed with atrazine show little effect on retention of atrazine by the membranes. This was caused by adsorption of atrazine on the surface of the catalyst forming large complexes which facilitated rejection by molecular sieving effect. TiO_2 catalyst has been reported in many studies for its effectiveness in degradation of organic matter. It has been noted in previous studies that photocatalytic process mainly occurs on the catalyst surface and not in the bulk solution (Li *et al*., 2002) hence the first step is adsorption on catalyst surface. In presence of HA and catalyst all membranes recorded retention of over 80%.

3.2 Influence of Solution pH, Feed Pressure and and Concentration

Figure 6 shows the flux of the membranes during atrazine filtration. Based on Fig. 6, it was obvious that the increase in pressure had significant effect on the permeate flux in the atrazine filtration tests. All membranes tested experienced approximately double increment of permeate flux when the operating pressure was doubled from 6 bar to 12 bar. This shows that permeate flux increment corresponded to the pressure applied to the solution and, therefore, concentration polarisation and fouling did not affected the filtration performance. Meanwhile, concentration of feed showed slight decrease of flux i.e., we are already above critical flux.

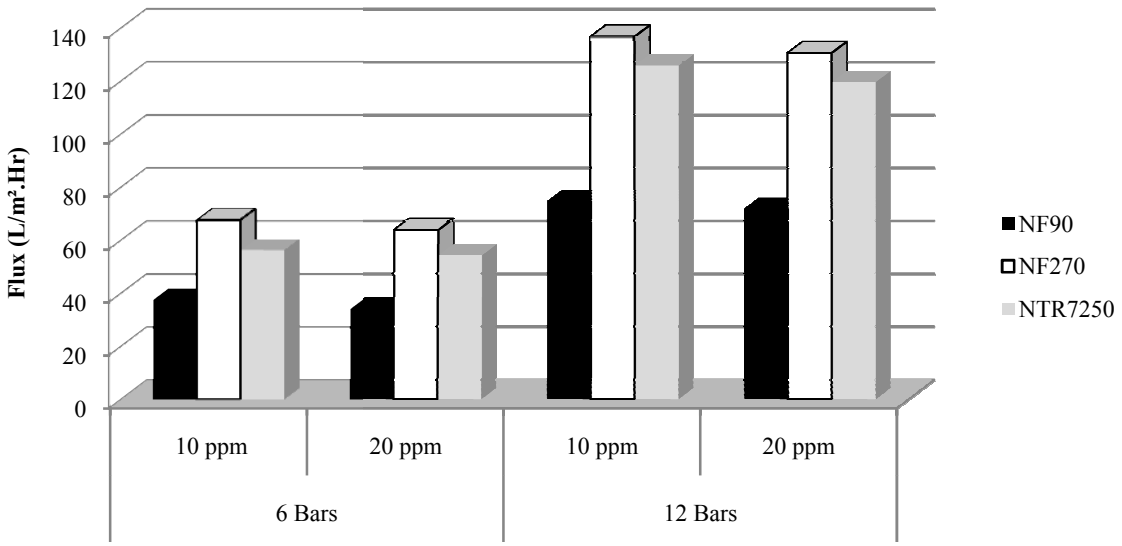


Figure 6: Membranes flux performance at temp. 25^{0}C, velocity 2.5 m/s, pH 8.3

NF270 produced the highest permeate flux for all conditions tested while NTR7250 showed the second highest. NF90 showed the lowest permeate flux among the membranes. Based on the published data, NF270 had average pore size of 0.71 nm, NF90 had average pore size 0.55 nm while NTR7250 had average pore size of 0.65 nm (Plakas *et al*., 2008, Zhu *et al.*, 2003). Hence, the results obtained in this study agreed with the average pore size reported in the literature, that the pore size has an influence on membrane permeate flux. However, this also showed that while 0.55 nm average pore size of NF90 was sufficient to retain atrazine with high percentage of rejection, solute-membrane interaction factor was also important (Bellona *et al.,* 2004, Kim *et al.*, 2005) as NF270 showed better retention than the NTR7250. The effect of solution pH on permeate flux is shown on Figure 7.

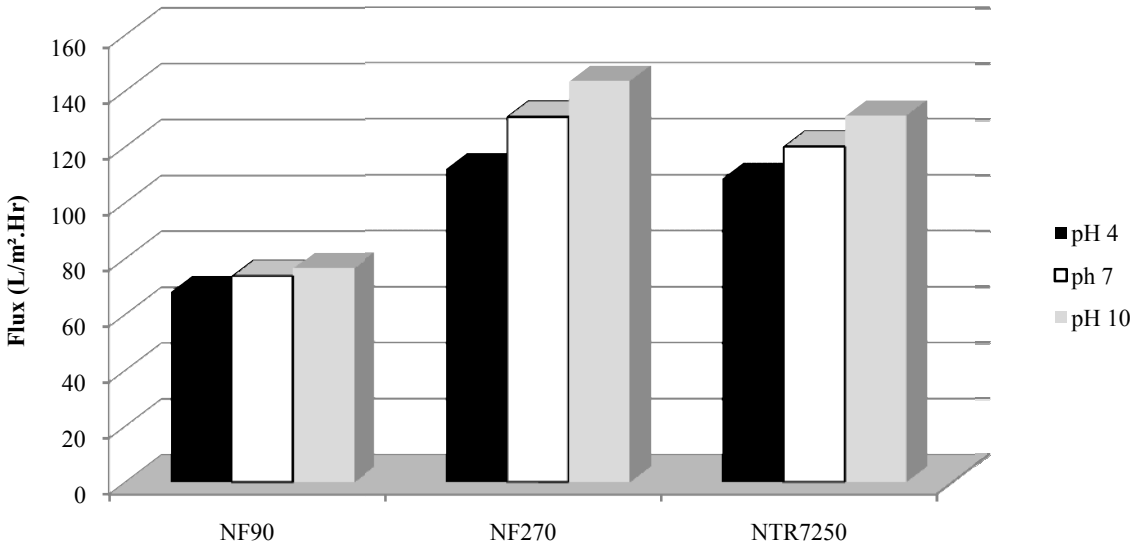


Figure 7: Membranes flux performance as a function of solution pH, at temp. 25^{0}C, vel. 2.5 m/s, pressure 12 bars, pH 8.3 and atrazine concentration 10 ppm

In all the membranes tested, the permeate flux was somewhat lower at pH 4 and at pH 7 while pH 10 recorded the highest permeate flux. This was probably caused by changes on membrane surface charge. It has been reported in several studies that above membranes isoelectric point, the negative surface charge of membrane increases. (Armad et al., 2008, Nyström *et al*., 1995). Hence, at high pH values the membrane becomes more hydrophillic and vice versa at low pH values. Increase in membranes hydrophilicity causes more water to permeate through the membrane pores resulting higher flux (Mänttäri *et al*., 2006).

3.3 Influence of HA and TiO_2 on Permeate Flux

The presence of HA in atrazine feed solution caused a decline in permeate flux while TiO_2 showed insignificant decline in flux as shown on Figure 8.

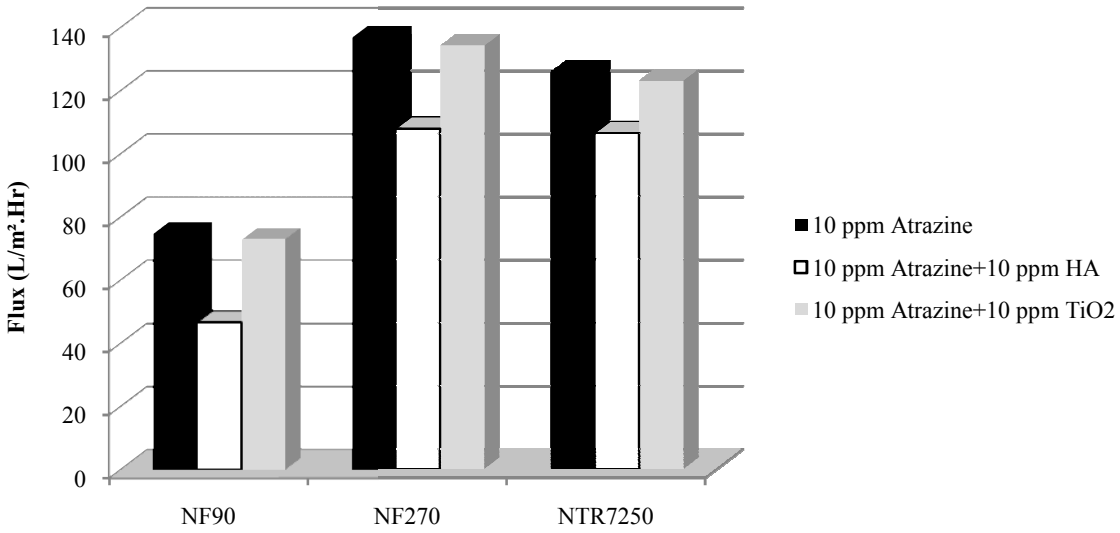


Figure 8: *Membranes permeate flux performance in presence of HA and TiO_2, at temp. 25^0C, crossflow velocity 2.5 m/s, pressure 12 bars, pH 8.3*

The permeate flux decline caused by HA was evident in all membranes tested. HA is hydrophobic and adsorbs easily on membrane surface. This adsorption leads to reduction in effective pore size causing reduction in permeability of the membrane. The organic matter adsorbs on TiO_2 surface and in the presence of light is degraded

4.0 Conclusion and Recommendations

The performance of nanofiltration membrane to retain atrazine in aqueous solution was examined in this study. Three nanofiltration membranes, NF90 and NF270 which have molecular weight cut-off of around 200 g/mol and NTR7250 with MWCO between 300 -450 g/mol, were subjected to laboratory crossflow filtration tests and the effects of feed concentration, operating pressure, pH, presence of HA and TiO_2 on the permeate flux and retention of atrazine were investigated. It was found that increasing the transmembrane pressure posed positive effect on atrazine retention and permeate flux.

However, the effect of feed concentration had negligible influence on the performance of the membranes tested. The pH of feed solution had influence on permeate flux and retention of the membranes tested. The best retention was achieved at pH 7 and lower at pH 4 and 10. Polar components such as pesticides have a lower retention when the membrane charge increases, because they are dipoles which can have a preferential orientation towards the membrane in the sense that the side of the dipole with a charge opposite to the membrane charge is the closest to the membrane. In this way, the preferential orientation results in an increased attraction, an increased permeation and thus a lower rejection. On the other hand, permeate flux increased with increasing pH and was attributed to changes in the surface charge of the membrane characteristics. Above the membranes isoelectric point (high pH), it became more hydrophilic hence more water permeated through and vice versa at low pH. In presence of humic substances, the rejection was found to increase while the flux declined which was attributed to adsorption of HA on the membrane surface, thus, narrowing down the membrane pores. TiO_2 presence led to an increase in rejection and did not much affect the permeate flux.

References

Acero J. L., Javier Benitez, F., Francisco J. R. and Carolina G. (2009). Removal of phenyl-urea herbicides in natural waters by UF membranes: Permeate flux, analysis of resistances and rejection coefficients, *Separation and Purification Technology*, Vol. **65** pp 322–330.

Ahmad A. L., Tan, L. S., Abd and Shukor, S. R. (2008). The role of pH in nanofiltration of atrazine and dimethoate from aqueous solution, *Journal of Hazardous Materials*, 154, pp 633–638.

Bandini S., Mazzoni, C. (2005). Modelling the amphoteric behaviour of polyamide nanofiltration membranes, *Desalination,* **184**, pp 327–336.

Bellona C., Drewes, J. E., Xu, P. and Amy, G. (2004). Factors affecting the rejection of organic solutes during NF/RO treatment - a literature review, *Water Resource*, pp 2795–2809.

Bruggen B. V., Schaep, J., Wilms, D. and Vandecasteele, C. (1999). Influence of molecular size, polarity and charge on the retention of organic molecules by nanofiltration*, J. Membr. Sci*., **156**, pp. 29–41.

Bruggen B. And Vandecasteele, C. (2003). *Removal of pollutants fromsurfacewater and groundwater by nanofiltration: overview of possible applications in the drinking water industry*, *Environ. Pollut*. **122** , pp 435–445.

Bonne P. A. C., Beerendonk, E. F., van der Hoek J. P. and Hofman, J. A. M. H. (2000). Retention of herbicides and pesticides in relation to aging RO membranes, *Desalination*, **132**, pp 189–193.

Bruggen, J. Schaep, W. Maes, D. Wilms, and Vandecasteele, C. (1998). Nanofiltration as treatment method for the removal of pesticides from ground waters, *Desalination* **117**, pp 139–147.

Chiou C. T., Malcolm, R. L., Brinton, T.I. and Kile, D. E. (1986). Water solubility enhancement of some organic pollutants and pesticides by dissolved humic and fulvic acids, *Environ. Sci. Technol*. **20**, pp 502–508.

Croplife foundation,August 2008, Demonstrating the Value of Herbicides for Smallholder African Farmers, Summary of Year One Project Activities.

Cyna B., G. Chagneaub, G. Bablon, Tanghe N. (2002). Two years of nanofiltration at the Mery-sur-Oise plant, France, *Desalination* **147**, pp 69–75.

Devitt E. C, F. Ducellier, P. Cot´e, M. R.Wiesner, (1998). Effects of natural organic matter and the raw water matrix on the rejection of atrazine by pressuredriven membranes, *Wat. Res.* **32** , pp 2563–2568.

Getenga Z., Ulrike Dörfler, Azuka Iwobi, Michael Schmid, Reiner Schroll, 2009, Atrazine and terbuthylazine mineralization by an Arthrobacter sp. isolated from a sugarcane-cultivated soil in Kenya*, Chemosphere* **77**, pp 534–539.

Herrera F. J. G, E. Gonzalez-Pradas, M. Fernandez-Perez, 2006, Controlled release of isoproturon, imidacloprid, and cyromazine from alginate-bentoniteactivated carbon formulations*, J. Agric. Food Chem.* **54**, pp 10053–10060.

Hofman, J. A. M. H., Beerendonk, E. F., Folmer, H. C. Kruithof, J. C. (1997). Removal of pesticides and other micropollutants with cellulose acetate, polyamide and ultra-low pressure reverse osmosis membranes, *Desalination,* **113**, pp 209–214.

Jones, M. N., Bryan, N. D. (1998). Colloidal properties of humic substances, *Adv. Colloid Interf. Sci.* **78** , pp 1–48.

Kamrin M. A., (1997). Pesticide Profiles: Toxicity, Environmental Impact and Fate, *CRC Press*, Boca Raton.

Kim M. H. and Yu, M. J. (2005). Characterization of NOM in the Han River and evaluation of treatability using UF–NF membrane, *Environ. Res.,* **97**, pp 116–123.

Kulikova N. A. and Perminova, I. V. (2002). Binding of atrazine to humic substances from soil, peat, and coal related to their structure, *Environ. Sci. Technol.* **36**, pp 3720–3724.

Li X. Z., Fan, C. M., Sun, Y. P. (2002). Enhancement of photocatalytic oxidation of humic acid in TiO2 suspensions by increasing cation strength, *Chemosphere,* **48**, pp 453–460.

Nghiem L. D., Schafer, A. I., Elimelech, M. (2004). Nanofilration of hormone mimicking trace organic contaminants, *Sep. Sci.Technol*., **40** pp 2633–2649.

Nghiem L. D. (2005). Removal of emerging trace organic contaminants by nanofiltration and reverse osmosis, *Doctorial Thesis*, University of Wollongong.

Nyström M., Lena Kaipia, Susana Luque, 1995, Fouling and retention of NF membranes, *Journal of membrane science,* Vol **98**, pp 249-262.

Ormad M. P, Miguel, N., Claver, A., Matesanz, J. M. and Ovelleiro, J. L. (2008). Pesticides removal in the process of drinking water production, *Chemosphere,* **71**, pp 97–106.

Plakas K. V., A. J. Karabelas, T. Wintgens, T. Melin, 2006, A study of selected herbicides retention by nanofiltration membranes—The role of organic fouling, *J. of Memb. Sc.*, **284**, pp 291–300.

Plakas K. V., Karabelas, A. J. (2008). Membrane retention of herbicides from single and multi-solute media: The effect of ionic environment, *J. of Memb. Sc.,* **320**, pp 325–334.

Plakas K. V., Karabelas, A. J. (2009). Triazine retention by nanofiltration in the presence of organic matter: The role of humic substance characteristics, *J. of Memb. Sc.* **336** pp 86–100.

Puasa S. W., (2006). Micellar-enhanced ultrailftration for removal of reactive dyes from an aqueous solution, *M.Sc. thesis*, Universiti Sains Malaysia, Penang.

Schafer A. I. N. Andritsos, A. J. Karabelas, E.M. V. Hoek, R. Schneider, Nystrom, M. (2005) Fouling in nanofiltration, in: A.I. Sch¨afer, A.G. Fane, T.D.Waite (Eds.), Nanofiltration: Principles and Applications, *Elsevier*, Oxford, UK.

Shaalan H. F., Montaser Y. Ghaly, Joseph Y. Farah, (2007). Techno economic evaluation of treatment of pesticide industry effluents using membrane schemes, *Desalination*, **204**, pp 265-276.

Spliid N., Koppen, B., (1998). Occurrence of pesticides in Danish shallow ground water, *Chemosphere*, **37**, pp 1307–1316.

United States Environmental Protection Agency, October 2001, The incorporation of Water Treatment Effects on Pesticide Removal and Transformations in Food Quality Protection Act (FQPA), DrinkingWater Assessments.

Verliefde A., Bas Heijman, Emile Cornelissen, Bart Van der Bruggen, Hans van Dijk, (2005). Modelling of removal of organic micropollutants by nanofiltration, *Workshop (developments in drinking water)*, KIWA.

World Health Organization, 2004, Guidelines for drinking-water quality, third ed. http://www.who.int/water sanitation health/dwq/gdwq3/ en/index.html.

Wittmann E., Cote, P., Medici, C., Leech, J. and Turner, A. G. (1998). Treatment of ahard borehole water containing low levels of pesticide by nanofiltration, *Desalination* **119**, pp 347–352.

Yoon Y., Westerhoff, P., Snyder, S. A. and Wert, E. C. (2006). Nanofiltration and ultrafiltration of endocrine disruptingcompounds, pharmaceuticals and personal care products*, J. Membr. Sci*. **270**,pp 88–100.

Zhang Y., van der Bruggen, B., Chen, G. X., Braeken, L. and Vandecasteele,C. (2004). Removal of pesticides by nanofiltration: effect of the water matrix, *Sep. Purif. Technol*. **38** pp 163–172.

Zhu A., Wanpeng Zhu, Zhuo Wu, Yifeng Jing, (2003). Recovery of clindamycin from fermentation wastewater with nanofiltration membranes, *Water research*, Vol.**37**, pp 3718-3732

Mänttäri, M., Pihlajamäki, A. and Nyström, M. (2006). Effect of pH on hydrophilicity and charge and their effect on the filtration efficiency of NF membranes at different pH, *Journal of Membrane Science*, **280**, pp 311-32

SUB-THEME IX

CROP STRESS SCIENCE FOR GREEN INNOVATION

UPRIGHT VARIETIES OUT-YIELD CLIMBING COWPEA VARIETIES AND LEAF STRIPPING AND DETASSELLING ENHANCES PRODUCTIVITY OF MAIZE/COWPEA INTERCROPS

A. B. Mashingaidze[1] and R. D. Katsaruware[2]
[1]Umutara Polytechnic, Nyagatare, Rwanda
[2] Crop Science Department, University of Zimbabwe, Mount Pleasant, Harare, Zimbabwe
E-mail abmash@yahoo.com

Abstract
An experiment to test the effect of cowpea architecture (two varieties with upright and bushy architecture and two with climbing architecture); three cropping systems (sole maize, sole cowpea and maize cowpea intercrop) and a maize leaf stripping/ detasselling treatment at anthesis (leaf stripped and detasselled, intact maize) on maize and cowpea grain yield and weed density and biomass at University of Zimbabwe Farm in the 2005/2006 season. Cowpea grain yield for the upright varieties was 2.5- 4 times higher than for the climbing varieties in maize cowpea intercrops. Cowpea vegetative biomass had a significant ($P<0.01$) but opposite trend with the climbing varieties having 1.46-1.62 more vegetative biomass at end of season than the upright varieties. Leaf-stripping and detasselling, averaged across the cowpea varieties, significantly increased cowpea grain yield by 5.46%, 1000 grain weight by 11.7%, number of grains per pod (11%) and number of pods per plant (17%). Upright cowpea varieties planted as sole crops suffered significantly less yield reduction (19.5%-36.6%) when intercropped with maize than one of the climbing varieties, R ex-Mbare (68.5%). Leaf stripping and detasselling in the maize bean intercrops increased maize grain yield by 12% compared to intact maize. The climbing cowpea varieties proved to be more competitive against maize, causing greater maize grain yield reduction (66%-67.7%) in maize cowpea intercrops than the upright cowpea varieties (29%-43%). Weed biomass was reduced by 46% in the intercropped treatments compared to the cowpea monocrop treatments. The results of the study show that new upright cowpea varieties are more adapted to be grown with maize in an intercrop than the traditional trailing and climbing cowpea varieties as they produced 2.5-4 times more cowpea grain and reduced maize grain yield by 24%-38% less than that caused by the trailing and climbing varieties.

Key words: Crop architecture, maize, cowpea, intercropping, leaf stripping, detasselling

1.0 Introduction

Cowpea is a widely grown legume that is commonly intercropped with maize in Southern Africa (Giller et al., 1993). Maize and cowpeas complement each other in the diet. Maize is a ready source of carbohydrates while cowpea is a rich source of proteins with 22-30% protein (Ledbetter, 2005). With the growing problem of malnutrition, which is evident in developing countries, a diet containing cowpeas is a possible way of alleviating protein deficiency.

Intercropping has remained popular in smallholder agriculture in Africa despite the emphasis on modern "green revolution" technologies such as monocropping, mechanization and use of pesticides by local research and extension (Richards, 1983). Various socio-economic and environmental reasons have been advanced to explain the widespread cereal-legume and cereal-cucurbit practices in semi-arid areas of Africa. These include the minimization of risk (Ruthenberg, 1980; Richards,1983; Tafera and Tana, 2002), higher net economic returns (Richards,1983), diversification of food supply (4) and more efficient use of environmental resources such as light, mineral nutrients and water (Richards, 1983; Ofori and Stern, 1987; Tafera and Tana, 2002). In addition intercrops have the potential to suppress weed germination, growth and seed production (Zimdahl, 1999) thereby reducing the number of times smallholder farmers hoe weed their crops to attain maximum yield (Mashingaidze *et al*., 2000). Maize cowpea intercropping is widely practiced by smallholder farmers in Zimbabwe (Mariga,1990); however there are currently no recommendations as to the complimentarity between maize and specific cowpea varieties with regards to productivity of the maize cowpea intercrops. Traditional varieties of cowpeas have a trailing and climbing architecture and these varieties have evolved under intercropping in smallholder farming systems in Southern Africa. New upright and bushy varieties of cowpeas are currently being promoted (Black Eyed Bean BEB and CBC_3) for production as monocrops by smallholder farmers in Southern Africa. Despite the recommendations that these varieties are best produced under monocropping conditions, farmers frequently intercrop these new upright cowpea varieties with maize. It is therefore necessary to investigate the adaptability of these new upright cowpea varieties to intercropping in comparison to the traditional climbing varieties.

Although intercropping has largely been shown to be advantageous in terms of greater efficiency of land utilization, yield of the dominated minor crop, grown under the canopy of the dominant cereal crop has always been low. Ofori and Stern (1987) reviewed 40 papers on cereal legume intercropping and found that the legume component crop yield declined an average of 52% and that of the cereal by 11% of their respective monocrop yields. Interception of most of the incoming Photosythetically Active Radiation (PAR) by the dominant cereal crop reduces dry matter production in the dominated legume crop reducing its grain yield. Any intervention, such as detasselling and leaf stripping, that increases the quantity of PAR intercepted by the minor crop in an intercrop, has potential to increase minor crop yield. In addition detasselling and leaf stripping can have a positive effect on dry matter allocation to the maize ear and therefore maize grain yield. Detasselling increases PAR interception by maize leaves (Hunter et al., 1969; Duncan *et al*., 1967) and removes apical dominance imposed by the tassel over the growth and development of the maize ear (Mostert and Marais, 1982; Subedi, 1996). Mashingaidze et al. (2004) found that the removal of 4-6 lowest leaves in maize at anthesis increased maize grain yield and attributed the maize grain yield increases to reduced transpiration during critical water stress sensitive stages of anthesis and grain-filling. Crookstone and Hicks (1988) found that positive yield response to defoliation was associated with low-end of the season available water. Shimada et al. (1992) found that grain yield of soybean was reduced by defoliation only under well watered conditions but was not affected defoliation in water restricted plants. We therefore hypothesized that leaf stripping and detasselling would enhance maize cowpea intercrop productivity

allowing more PAR to reach the cowpeas in the maize under storey and by directly influencing dry matter accumulation in the maize ear.

The objectives of this study were therefore to determine the adaptability of upright and bushy cowpea varieties (Black Eyed Bean BEB, CBC_3) and climbing and trailing cowpeas varieties (Local Landrace and Red ex Mbare) for intercropping with intact maize and maize modified by detasselling and leaf stripping from two points of view (a) productivity of the component crops and (b) the ability of each maize cowpea cultivar combination to suppress weeds.

2.0 Materials and Methods

The experiment was carried out at the University of Zimbabwe Farm, 14 km north-west of the city of Harare in Zimbabwe in the 2005/2006 season. The experiment was set up as a 4*3*2 factorial in a randomized block design. The first factor was the cowpea variety with four levels, two upright and bushy varieties (Black Eyed Bean (BEB), CBC_3) and two trailing and climbing varieties (Local Landrace and Red ex Mbare). The second factor was cropping system with three levels; sole cowpea, sole maize and maize-cowpea intercrop. The third factor is leaf stripping and detasseling treatments that was imposed on treatments with maize only (a commercial hybrid SC 637); (a) four bottom leaves of maize stripped (leaf stripping) and the tassel removed (detasselled), (b) the maize left intact (unstripped and tasselled). Each treatment was replicated three times and plot size was 4.5×6m.

The land was ploughed and disc harrowed in November before planting in December 2005. Maize was planted at 90 cm (between-rows) and 30 cm (in-row) spacing to attain a plant density of 37 000 plant ha^{-1}. Cowpeas were planted at 45 cm (between rows) and 20 cm (in-row) spacing to attain a density of 111 000 plants ha^{-1}. In the maize cowpea intercrops, the maize spatial arrangement and density was maintained and cowpeas were planted in the middle of each maize row, ultimately attaining 90 cm × 20 cm spacing and 55 000 plants ha^{-1}. A basal fertilizer dressing of 150 kg ha^{-1} of compound D (7%N, 14%P_2O_5, 8%K_2O) and single super phosphate (19% P_2O_5) was banded into planting furrows before seeding for maize and cowpeas, respectively. Maize was top-dressed with 150 kg ha^{-1} Ammonium Nitrate (34.5% N) at 5 weeks after emergence (WAE) in the sole crops and intercrops.

Leaf stripping and detasselling was carried out at 50% silking (when 50% of the maize plants have produced silks). Four lowest leaves that were green were pulled and detached at the junction of the stem and the leaf sheath. Detasselling was done by pulling the tassel stalk upwards until the tassel popped out of the funnel, without damaging any sub-tassel leaves.

Weed density and biomass were measured at 6 WAE and at maize physiological maturity. Three 30cm × 30cm quadrants were randomly thrown into each plot, weeds were counted, cut at ground level, put into brown paper bags and dried at 80°C for 48 hours and then weighed. Weed density was square root transformed (Steel and Torrie, 1984) before analysis of variance (ANOVA). The yield and yield components of cowpeas were determined at cowpea physiological maturity when the pods were brown and the beans rattled within the pods. A random sample of five plants was selected and number of pods per plant, number of beans per pod, 1000-grain weight and biomass of cowpea plants was measured. Cowpea yield was measured from a 4m×3.6m net plot and moisture content was determined using a moisture meter and grain yield standardized to 11% moisture content (mc) before statistical analysis. Maize 1000 grain weight and grain yield was measured after harvesting cobs from a 4m×3.6m net plot, measuring grain moisture content and standardizing to 12.5% mc.

ANOVA was carried out on all data and where significant treatment effects were detected at $P<0.05$, means were separated using the least significant difference (lsd). Intercrop productivity was analyzed using Land Equivalent Ratios (Mead and Willey, 1980).

3.0 Results

3.1 Cowpea Grain Yield and Yield Components in Maize-Cowpea Intercrop

Cowpea cultivar ($P < 0.01$) and leaf stripping and detasselling of the maize ($P < 0.05$) significantly affected cowpea yield components and grain yield. Number of pods per plant, grains per pod and grain weight significantly and progressively increased from Red ex Mbare, Local Landrace, and BEB and was highest in CBC_3. The test weight (1000 grain weight,) an indicator of the size of grain and the extent of grain filling, was significantly higher in the variety BEB than in CBC_3 and the Red ex Mbare cultivars. There was no significant difference in 1000 grain weight between BEB and the Local Landrace (Table I).

Cowpea residual vegetative biomass harvested at the end of the season had an opposite trend to all the grain yield parameters. Vegetative biomass of the Local Landrace and Red ex Mbare, the climbing cultivars was 33.7%-38% higher than for CBC_3 and BEB, the improved upright types of cowpeas (Table I).

Leaf stripping and detasselling of maize in a maize-cowpea intercrop significantly ($P < 0.05$) influenced cowpea grain yield components (number of pods per plant, grains per pod, 1000 grain weight and grain yield and did not affect ($P > 0.05$) cowpea biomass Leaf stripping and detasselling maize at anthesis in a maize-cowpea intercrop resulted in a 14.65%, 10.51% and 5.18% increase in number of pods per plant, 1000 grain mass and cowpea grain yield, respectively, when compared to cowpeas grown under intact maize (Table II).

3.2 Maize Grain Yield and 1000-Grain Weight in the Intercrop and Monocrop

Leaf stripping and detasselling maize in a maize-cowpea intercrop ($P < 0.05$) significantly affected the size of maize grains as well as the grain yield. Maize yield and 1000 grain weight increased by 12% and 11.7% respectively in leaf stripped and detasselled maize compared to intact maize averaged across cowpea cultivars. Significantly higher grain yield (10.6%) and 1000 grain weight (9.6%) were recorded in leaf stripped and detasselled maize than in intact maize averaged across the cowpea varieties and cropping system treatments (Table III).

Cowpea cultivar in a maize-cowpea intercrop had a highly significant effect on maize grain yield ($P < 0.01$). Maize intercropped with the upright cowpea cultivars (BEB and CBC_3) had 16.1%-29.8% higher grain yield than maize intercropped with the trailing Local landrace and Red ex Mbare (Table IV).

Monocropped maize had significantly higher grain yield than intercropped maize (Table IV). Intercropping maize with CBC_3, BEB, Local landrace and Red ex Mbare caused 29.15%, 43.05%, 66.13%, and 67.66% maize grain yield reductions respectively when compared to sole maize. Although the test weight of monocrop maize was highest, it did not significantly differ with the test weights attained when the maize was intercropped with all the four cowpea cultivars (Table IV).

3.3 Weed Density and Biomass

Cropping system had a highly significant effect ($P < 0.01$) on weed density and biomass at 6 WAE and at maize physiological maturity. More (47%) numbers and greater (37%) biomass of weeds were recorded in the maize cowpea intercrop than in the sole cowpeas, early in the season, at 6 WAE. The opposite was true at maize physiological maturity, with twice as many and 87% greater weed biomass being recorded in the sole cowpea crops than the maize cowpea intercrops (Table V).

3.4 Productivity of Maize-Cowpea Intercrops

The productivity of maize-cowpea intercropping system with leaf stripping and detasselling was assessed through comparisons of Land Equivalent Ratios (LER) of the treatment combinations. The partial LERs for maize in a maize-cowpea intercrop was calculated based on unstripped intact sole maize (Table VI). Leaf stripping and detasselling conferred an 11% yield advantage over intact maize in sole maize. The LER when cowpeas were intercropped with intact maize was 1.54, 1.4, 1.34 and 1.17 for BEB, CBC_3, L. Landrace and R. ex-Mbare and when intercropped with leaf stripped and detasselled maize was 1.61, 1.63, 1.5 and 1.17, respectively, indicating gains in the efficiency of land use when maize was leaf stripped and detasselled and intercropped with upright cowpea varieties (BEB and CBC_3) and the trailing and climbing L. Landrace. Generally higher LERs were recorded with intercrops when maize was leafstripped and detasselled. The highest LER (1.63) was produced by maize-CBC_3 intercrop with maize leafstripped and detasselled (Table VI).

4.0 Discussion

The climbing cowpea varieties in this study allocated a greater proportion of their total dry matter to vegetative plant parts and less to grain yield when compared to upright cowpea varieties. This strategy enabled the these varieties to climb and entwine maize stalks up to the tassel, however pod formation and grain development in these varieties seemed to be very sensitive to photon flux density of PAR as the little yield they produced was observed to be confined to the tips of the vines that were exposed to full PAR at the top of the canopy, the rest of the shaded bean plant did not carry grain. Our results also show that the climbing varieties did not fare any better under monocrop conditions, climbing varieties produced grain yield that was 0.31-0.42 of the upright varieties grain yield (Table VI).They displayed a high propensity to allocate dry matter to vegetative materials (leaves, stems and petioles) under monocrop conditions. It was also apparent that the commercial plant densities that we used for cowpeas were too high for the climbing varieties, we observed that smallholder farmers use lower (half of the plant density that we used) when planting climbing varieties in both monocropping and intercropping situations. Excessive mutual shading reduced the grain yield of these climbing varieties when planted as sole crops, given the sensitivity of grain yield of these climbing varieties to photon flux density that we observed in the intercrops. Maize suffered 16.1-29.8% greater yield loss when intercropped with climbing cowpea varieties than when intercropped with upright cowpea varieties (Table IV) showing that the climbing varieties were more competitive against maize in the intercrops. When climbing varieties entwine the maize plant, their foliage causes partial shading of the maize canopy, reducing photosynthetic production and maize grain yield. Upright cowpea varieties on the other hand occupy the under-storey of the maize canopy and exert less influence on the total PAR intercepted by the maize plant compared to climbing varieties. The apparent high sensitivity to low PAR conditions in the canopy and the greater levels of competitiveness for PAR against maize displayed by the climbing cowpea varieties indicates less adaptability of the climbing cowpea varieties to intercropping when compared to upright varieties, our results suggest.

In this study, leaf stripping and detasselling of the maize consistently increased maize grain yield and 1000 grain mass by 11-12% in intercropped and sole maize. Increases in maize grain yield due to detasselling have been attributed to increased radiation interception by maize leaves as a result of removal of the “tassel shading effect” and/or the removal of the apical dominance effect (Mostert and Marais, 1982; Subedi, 1996). Barbieri *et al*., 2000 and Andrade et al., 2002 observed that increased radiation penetration into the maize canopy during the critical three week period bracketing anthesis resulted in increases in kernel number and kernel weight, as observed in this study on leaf stripping and detasselling. In previous research Mashingaidze *et al*., (2004) it was established that removal of bottom 4-6 leaves at 50% silking (leaf stripping) significantly increased maize grain yield and we attributed the

maize grain yield increases to the removal of senescing leaves which if they remain on the plant would transpire and subject the plants to water deficits during critical moisture stress sensitive stages of anthesis and grain filling. Crookstone and Hicks (1988) provided evidence that partial defoliation of the maize plant conserved water in the plant and alleviated the yield reducing effects of drought stress in dry seasons but had no effects on grain yield in wet seasons. Leaf stripped, detasselled and leaf stripped and detasselled maize achieved significantly higher rates of ear growth rate when compared to intact maize, however the combined effect of leaf stripping and detasselling was not higher than that of detasselling or leaf stripping on their own, indicating that the two interventions affected the same process, but were not additive (Mashingaidze *et al*., 2004). Our results also show that leaf stripping and detasselling benefited cowpea grain yield components and total grain yield as a result of increased PAR penetration into the lower echelons of the canopy occupied by the cowpeas. The effects of leaf stripping and detasselling on maize and cowpea grain yield resulted in the higher efficiencies of land use as measured by LER that were recorded in leaf stripped and detasselled treatments than intact ones, in this study (Table VI). These results show that leaf stripping and detasselling is a technological intervention that has potential be deployed by smallholder farmers to increase the productivity of intercrops by increasing both maize grain yield and minor crop yield.

The results of this study show that sole cowpea crops suppressed weeds more than the maize cowpea intercrops early in the season but the trend was reversed late in the season when the maize cowpea intercrops reduced weed density and biomass more than the sole cowpea crops. These results suggest that the maize cowpea intercrop is more effective in suppressing late weeds than the sole cowpea crops. These results are similar to what has been observed by (10).

5.0 Conclusions

In conclusion the results of this study indicate that the new upright cowpea varieties are adaptable to be intercropped with maize as they produced more cowpea grain yield and competed less with the maize (caused less reduction in maize grain yield in maize cowpea intercrops) than the climbing varieties; leaf stripping and detasselling has potential to increase intercrop productivity by increasing the maize and the cowpea grain yield and maize cowpea intercrops can reduce emergence and growth of (late) weeds.

References

Andrade, F. H., Calviño, P., Cirilo, A. and Barbieri, P. (2002). Yield responses to narrow rows depend on increased radiation interception. *Agronomy Journal,* **94**, pp 975-980.

Barbieri, P. A., Sainz Roza, H. R., Andrade F. H. and Echeverria H. E. (2000). Row spacing effects at different levels of nitrogen availability in maize. *Agronomy Journal,* **92**, pp 283-288.

Crookstone K. R. and Hicks D. R. (1988). Effect of early defoliation on maize growth and yield: An eleven year perspective. *Crop Science*, **28**, pp 371-373.

Duncan, W. G., Williams, W. A. and Loomis, R. S. (1967). Tassels and the productivity of maize. *Crop Science,* **7**, pp 37-39.

Francis C. A. (1985). Intercropping: Competition and yield advantage. In R. Shibles (Ed.*), World Soybean Research Conference III.* Westview Press, Boulder, Colorado, pp1017-1024.

Giller K. E., McDonagh, J. F. and Cavendish, G. (1993). Can biological nitrogen fixation sustain agricultural production in the tropics? In J.K. Syers and D. L. Rimmer (Ed.), *Soil Science and Sustainable Land Management.* C.A.B. International, Wallingford. pp 173-192.

Hunter R. B., Daynard T. B., Hume D. H., Tanner J. W., Curtis J. D. and Kannenberg L. W. (1969). Effects of tassel removal on grain yield of corn (*Zea mays* L.) *Crop Science,* **9**, pp 405-406.

Ledbetter K.(2005). Cowpeas could add sustainability to cropping systems. Agnews, Texas a & M University System Agriculture Program http//newsagnews.tamu.edu/dailynews/stories/SOIL/Oct0405a.htm

Mariga, I. K. (1990). Effect of cowpea planting date and density on the performance of maize-cowpea intercrop. *Zimbabwe Journal of Agricultural Research,* **28**, pp 125-131.

Mashingaidze, A. B**.**, Hupenyu, A. and Nyakand, C. (2006). Leaf stripping and detasselling increases maize cob growth rate and grain yield. Combined Cogress, University of KwaZulu Natal, 23-26 January, 2006.

Mashingaidze, A. B., Nyakanda C., Chivinge O. A., Mwashaireni A.and Dube K. W. (2000). Influence of maize-pumpkin live mulch on weed dynamics and maize yield. *African Plant Protection* 6(1):57-63.

Mashingaidze, A. B., van der Werf W, Lotz L. A. P., Kropff M. J., Mudita, I. and C. Nyakanda 2004. Leaf stripping and detasselling increases maize grain yield. *Tropical Resources Management Papers,* **57**, pp 15-30.

Mead, R. and Willey, R. W. (1980). The concept of a 'land equivalent ratio' and advantages in yields from intercropping. *Experimental Agriculture,* **16**, pp 217-228.

Moster, A. J. and Marais, J. N. (1982). The effects of detasselling on the yield of irrigated maize. *Crop Production/Gewasproduksie* XI: pp 163-167.

Norman, D. W., Simmons, E. B. and Hays, H. M. (1982). Farming systems in the Nigerian Savannah: Research and strategies for development. Westview Press, Boulder, Colorado.

Ofori, F. and Stern W. R. (1987). Cereal-legume intercropping systems. *Advances in Agronomy*, **41**, pp 41-87.

Richards, P. (1983). Ecological change and politics of African land use. *African Studies Review,* **26**, pp 1-72.

Ruthenberg, H. (1980). Farming systems in the Tropics. Oxford Press, Oxford.

Shimada, S., Kokobun, M. and Shibata, H. (1992). Effect of water supply and defoliation on photosynthesis, transipiration and yield of soybean. *Japanese Journal of Crop Science* **61**(2), pp 264-270.

Steel, R. G. D. and Torrie, J. H. (1984). Principles and Procedures of Statistics. 2nd Edition. MacGraw-Hill, New York.

Subedi, K. P. (1996). Effect of leaf stripping, detasselling and topping of maize on maize and relay intercropped finger millet. *Experimental Agriculture,* **32**: 57-61.

Tafera, T. and Tana, T. (2002). Agronomic performance of sorghum and groundnut cultivars in sole and intercrop cultivation under semi-arid conditions. *Journal of Agronomy and Crop Science,* **188**, pp 212-218.

Willey, R.W. (1990). Resource use in intercropping systems. *Agriculture and Water Management* **17**, pp 215-231.

Zimdahl, R. L. (1999). Fundamentals of weed science. Academic Press, San Diego.

Table 1: Effect of cowpea cultivar on grain yield and yield components of cowpeas in maize-cowpea intercrops

Cultivar	# of pods plant $^{-1}$	# of grains pod $^{-1}$	1000 grain weight (g)	Grain yield kg ha^{-1}	Plant biomass kg ha^{-1}
BEB	3.00c[1]	9.2c	184.77c	119.21c	88.79a
CBC_3	3.33d	11.0d	147.27b	135.07d	85.80a
Local Landrace	2.23b	6.9b	170.24c	47.02b	129.56b
Red ex Mbare	1.13a	1.63a	88.94a	34.20a	140.21b
P-value	0.000	0.000	0.000	0.000	0.010
Sed	0.12	0.50	6.71	2.19	16.58
Lsd $_{0.05}$	0.26	1.07	14.35	4.71	35.49

[1]Means followed by the same letter in a column are not significantly different at P<0.05

Table 2: Effect of leaf stripping and detasselling maize on cowpea grain yield and yield components in maize-cowpea intercrops

Leaf stripping and detasseling	# of pods plant^{-1}	# of grains pod^{-1}	1000 grain weight g	grain yield kg ha^{-1}	plant biomass kg ha^{-1}
Leaf strip detass	2.62b[1]	7.58b	156.00b	86.11b	122.59
Intact maize	2.23a	6.82a	139.60a	81.65a	99.59
P-value	0.001	0.047	0.004	0.013	0.07
Sed	0.09	0.35	4.74	1.55	11.73
$LSD_{0.05}$	0.18	0.75	10.14	3.33	NS

[1]Means followed by the same letter in a column are not significantly different at P<0.05

Table 3: Effect of leaf stripping and detasselling on maize grain yield in the maize cowpea intercrop and averaged across intercrop and monocrop treatments

	Maize cowpea intercrops		Averaged across monocrop and intercrop treatments	
Treatment	1000 grain grams	Grain yield tons ha^{-1}	1000 grain grams	Grain yield tons ha^{-1}
Leaf strip detass	536.32b[1]	5.17b	538.02b	5.67b
Intact maize	473.56a	4.60a	486.45a	5.07a
P value	0.043	0.028	0.038	0.000
Sed	28.27	0.23	23.05	0.19
$Lsd_{0.05}$	60.50	0.50	48.40	0.41

[1]Means followed by the same letter in a column are not significantly different at P<0.05

Table 4: Effect of cowpea variety on maize grain yield and test weight and comparisons of monocropped maize grain yield and test weight to maize in maize-cowpea intercrops

cowpea cultivar	1000 grain weight (g)	Grain Yield (tonnes ha^{-1})
BEB	441.45	5.11b
CBC_3	544.58	5.66c
Local Landrace	503.23	4.40a
Red ex Mbare	530.48	4.36a
Maize monocrop	541.43	7.31d
P-value	0.060	0.000
Sed	36.44	0.12
$LSD_{0.05}$	NS	0.252

Table 5: Effect of cropping system on weed density and biomass at 6 WAE and at maize physiological maturity 17 WAE

	6 weeks after emergence		At maize physiological maturity	
Cropping System	weed density number m^{-2}	weed biomass grams m^{-2}	weed density number m^{-2}	weed biomass grams m^{-2}
Sole cowpea	13.40a[1]	4.72a	13.76b	2.69b
Maize-cowpea	19.75b	6.48b	6.78a	1.44a
P value	0.001	0.000	0.000	0.001
Sed	1.46	0.32	0.69	0.30
$Lsd_{0.05}$	3.12	0.68	1.48	0.63

[1]Means followed by the same letter in a column are not significantly different at P<0.05

Table 6: Land Equivalent Ratio (LER) analysis of treatment combinations in a maize- cowpea intercropping experiment

Treatment	maize grain yield t ha^{-1}	pLER[1] maize	cowpea grain yield kg ha^{-1}	pLER cowpea	LER
Sole maize					
Intact	6.94	1	_	_	1
Leafstripped and detasselled	7.68	1.11	_	_	1.11
Maize- cowpea intercrop					
Leaf strip and detass & BEB	5.35	0.77	118.98	0.84	1.61
Intact &BEB	4.88	0.70	119.44	0.84	1.54
Leaf strip and detass & CBC_3	6.11	0.88	140.05	0.75	1.63
Intact &CBC_3	5.20	0.71	130.09	0.69	1.4
Leaf strip and detass & L.landrace	4.70	0.68	49.24	0.82	1.5
Intact and L.landrace	4.10	0.88	44.81	0.74	1.62
Leaf strip and detass & ex, Mbare	4.51	0.65	36.16	0.52	1.17
Intact and ex, Mbare	4.23	0.61	32.25	0.56	1.17
Sole cowpea					
BEB	_	_	142.49	1	1
CBC3	_	_	187.27	1	1
Local landrace	_	_	59.61	1	1
Red ex Mbare	_	_	57.64	1	1

pLER[1] = partial Land Equivalent Ratio

MALDI-TOF/MS BASED SCREENING OF PLANT-GROWTH PROMOTING *METHYLOBACTERIUM* SPECIES COLLECTED FROM VARIOUS PLANTS

A. Tani
Institute of Plant Science and Resources, Okayama University, Kurashiki, Okayama, Japan

Abstract
Plants emit many kinds of volatile organic compounds, including methanol as a main compound. The global methanol emission from plants is estimated at 100 mega tones per year. Recent metagenomic analysis revealed the predominance of *Methylobacterium* species in phyllosphere (plant surface). These species are characterized by their ability to grow on methanol as a sole carbon and energy source. Thus it is considered that such ability is advantageous for these species to grow in relatively nutrient-poor environment as plant surfaces. Also these species are known to have an ability to promote plant growth. They are reported to produce phytohormones (auxin, cytokinin), siderophores, and vitamin B12, and to have ACC deaminase that can inhibit ethylene biosynthesis. Also they have abilities of calcium phosphate solubilization and nitrogen fixation. These abilities are believed to be involved in plant growth promotion. The genus *Methylobacterium* contains 35 known species, and there is an increasing number of new isolates. But the interaction specificities between them and plants, and specificity of plant-growth promotion ability is not clear yet 200 strains of *Methylobacterium* from various plants were collected and subjected to MALDI-TOF/MS analysis for protein profiling of the isolates. The technique allowed identification and clustering of the isolates in a day. The selected unique strains were further subjected to 16S rRNA gene analysis, and their phylogenetic position was revealed. Using the same unique strains, efforts are in placeto find the best combination of strains and plant species. In this presentation I would like to introduce the result of the screening and the effect of inoculation to barley are discussed. As a conclusion, MALDI-TOF/MS-based screening allows maximization of isolates library, fast identification, and selection of unique strains. The technique can be used to find the best strain for specific plants.

Key words: Methanol, *Methylobacterium* sp. MALDI-TOF/MS

1.0 Introduction

The activities of the microorganisms inhabiting plant surface have great effect on plant growth. Some of them are known to evoke diseases in plants, and others help plant growth through nitrogen fixation, siderophore production, phosphate solubilization, and plant hormone biosynthesis. Utilization of such beneficial microorganisms is expected to make a low-cost and safe biofertilizer. But the mode of interaction between microorganisms and plants has to be understood first.

On the other hand, it is known that the global methanol emission from plants is about100 mega tones per year. Recent metagenomic analysis revealed the predominance of *Methylobacterium* species in phyllosphere (plant surface), which are capable of growing on methanol as a sole carbon and energy source. Also these species are known to have an ability to promote plant growth. In this study, *Methylobacterium* strains collected from many plant samples were evaluated with high-throughput mass spectrometry-based analysis. Then their ability to promote barley growth was investigated. The result of pot cultivation experiment are here reported.

2.0 Materials and Methods

100 samples of plants growing at the Institute of Plant Science and Resources, Okayama University were collected. Those species included rice, wheat, tree, grasses, and mosses. Water suspensions of the samples were spread onto “methanol medium” solidified with agar. The media contained methanol as a sole carbon and energy source. In our screening, pinkish colonies were selectively isolated, and further purified by streaking. A total of 400 bacterial strains were isolated. Methanol assimilation of these isolates was further verified by cultivating them in liquid methanol medium, resulting in final selection of 200 strains. The isolates were then subjected to MALDI-TOF/MS analysis (2).

Bacterial colonies formed on the solid media were picked up with toothpicks, and the bacterial cells were directly smeared onto MALDI target plate. A matrix solution (10 mg/ml Sinappinic acid in 50% acetonitrile plus 2.5% trifluoroacetate) was dropped onto the samples. For mass standards, *Escherichia coli* cells were used because the masses of its ribosomal proteins are known. The spectra of isolates were aligned and analyzed to construct a phylogenetic tree using UPGMA method. The analysis included all the type strains in the genus. The isolates found to be unique in the tree were further selected and subjected to 16S rRNA gene analysis. The 16S rRNA gene analysis was done according to the method described previously (3). As a result, a non-overlapping library of 80 *Methylobacterium* strains was constructed.

The library was used to screen the best strain that can promote barley growth. In the first screening, sterilized barley seeds were placed on solidified soil extract solution, and bacterial suspensions were applied. The strains that showed growth promotion were selected, and this screening was done thrice for 80 strains. Finally, 8 selected strains were subjected to pot growth experiments in a greenhouse.

3.0 Results and Discussion

Among the 80 strains selected by MALDI-TOF analysis, up to 20 strains seemed to be novel species within the genus *Methylobacterium*. Thus, our high-throughput strategy can be successfully applied to screen novel species within the library. This method is very powerful for taxonomical study, within any library of microorganisms, including yeasts, and fungus. The novel species are currently being investigated for new species description.

In this study, the relation between isolation source and the isolates was also analyzed. The isolates belonging to *M. radiotolerance* and *M. extoquens* group were ubiquitously found in many plant species. The isolates derived from moss samples appeared to be quite unique, and most of the novel isolates were indeed from moss samples.

To examine if the isolates selected by our screening promote plant growth, 8 strains were applied to barley seeds. Effect of these strains on barley growth were measured. The result showed that total plant mass and grain yield were not improved by the application of these isolates. However, it was observed that a significant decrease in grain number and an increase in 100 seeds weight. This result implicates that although plant mass is not largely affected, application of our isolates can possibly alter plant growth, particularly in the formation of reproductive organs. Based on these observations, it was inferred that barley grain quality can be improved by the application of some isolates identified in this study.

References

Delmotte, N. *et al*., (2009). PNAS 106, 16428-16433.

Holland, R. D. *et al*., (1996). Rapid Commun Mass Spectrom, **10**, pp 1227.

Lane, D. J., (1991). In Nucleic *Acid Techniques in Bacterial Systematics*, pp. 115-175.

Edited by E. Stackebrandt and M. Goodfellow. Chichester: Wiley.

DETERMINATION OF ENDOPHYTIC BACTERIA COMPOSITION OF RICE SEED USING DGGE

C. N. Ngamau[1], M. Hunja[2], A. Tani[3]
[1,2]Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[3]Institute of Plant Science and Resources, Okayama University, Kurashiki, Okayama, Japan
E-mail: cngamau@rpe.jkuat.ac.ke

Abstract
Endophytic bacteria have a potential role in promoting plant growth and suppressing disease pathogens in a cost effective and environmentally friendly manner. This study was therefore conducted with the aim of determining the endophytic bacteria composition of rice seeds collected in Kenya in view of their agronomic importance. Different varieties of rice seeds were collected from Bunyala, Hola, Kaloleni, Mwea, Msabweni, and Taveta in Kenya. Rice seeds were surface-sterilized and bacterial DNA isolated. Partial 16SrRNA gene was amplified using Denaturing Gradient Gel Electrophoresis (DGGE) primers. Endophytic bacterial gene fragments from five samples of rice seed varieties were successfully amplified. Amplified DNA was then subjected to DGGE and a total of 41 DNA bands were excised from the gel. The excised DNA bands were then re-amplified and 31 out of the 41 PCR products obtained were sequenced for endophytic bacteria identification. Bacteria strains were identified as *Methylobacteriaceae*, *Sphingomonadaceae*, *Enterobacteriaceae*, *Pseudomonadaceae, Flavobacteriaceae* and *Rhizobiaceae*. *Methylobacterium* species, for example, are very important organisms, which have been shown to stimulate seed germination and plant development, perhaps through production of phytohormones. The next stage of this study will be to isolate such specific bacterial strains and determine their agronomic importance on rice production in Kenya.

Key words: Denaturing Gradient Gel Electrophoresis (DGGE), endophytic bacteria, rice

1.0 Introduction

Rice (*Oryza sativa*) is the third most important staple food after maize and wheat in Kenya, forming part of the larger diet for urban population (EPZA, 2005; MoA, 2009). About 80% of the rice in Kenya is grown under irrigation in paddy schemes managed by the National Irrigation Board (NIB) while the remaining 20% is rain fed (MoA, 2009). In 2009, Kenya's rice production was estimated to be in the range of 45,000 and 80,000 tons per annum, against an annual consumption of 300,000 tons. The deficit is met through imports, which were valued at KSH 7 billion in 2008. The annual rice consumption in Kenya is increasing at a rate of 12% as compared to 4% and 1% for wheat and maize respectively. This can be attributed to progressive change in eating habits. With such a rising consumption of rice in Kenya and indeed worldwide, rice yield must be increased. However, increased crop production results to higher production cost and environment degradation because of excessive use of chemical fertilizers and other inputs, which is not sustainable. In Kenya, the high cost of chemical fertilizers is also a challenge for the resource poor farmers. Sustainable production of rice will hence mean increasing the rice yield without the mass use of chemical fertilizers and pesticides. For this reason, scientists are consistently exploring biological alternatives, which are cost effective and environment friendly. Some of these biological alternatives are the endophytic bacteria, which have beneficial characteristics to the cultivation of plants (Long *et al*., 2008). Endophytic Bacteria are present in most plant species, residing latently or actively colonizing plant tissues without causing any apparent disease symptoms (Hallmann *et al*., 1997; Tan and Zou, 2001).

Traditional plating techniques (culture-based methods) usually result in underestimation of bacterial diversity; for example, only less than 10% of the total bacterial community in soil is detected (Torsvik *et al*., 1990). Therefore, molecular fingerprinting techniques independent of culturing and based on small-subunit (SSU) rRNA genes (rDNA) have become popular in addressing the problems of diversity, structural composition and dynamics of microbial communities (Mano and Morisaki, 2008). Denaturing gradient gel electrophoresis (DGGE) is a molecular fingerprinting method that separates polymerase chain reaction (PCR)-generated DNA products (http://www.eeescience.utoledo.edu/faculty/sigler/research/protocols/dgge/dgge.pdf).

The polymerase chain reaction of environmental DNA can generate templates of differing DNA sequence that represent many of the dominant microbial organisms. However, since PCR products from a given reaction are of similar size (bp), conventional separation by agarose gel electrophoresis results only in a single DNA band that is largely non-descriptive. DGGE can overcome this limitation by separating PCR products based on sequence differences that results in differential denaturing characteristics of the DNA. During DGGE, PCR products encounter increasing concentrations of chemical denaturant as they migrate through a polyacrylamide gel. Upon reaching a threshold denaturant concentration, the weaker melting domains of the double-stranded PCR product will begin to denature at which time migration slows dramatically. Differing sequences of DNA (from different bacteria) will denature at different denaturant concentrations resulting in a pattern of bands. Each band theoretically representing a different bacterial population present in the community.

2.0 Materials and Methods

2.1 Bacteria DNA Isolation

Different varieties of rice seeds were collected from various growing regions of Kenya courtesy of the National Irrigation Board and farmers of Kaloleni and Hola. About 10 rice seeds per variety were put into 50 ml tube and washed with sterile MilliQ water (vortex and decantation). The seeds were then surface-sterilized with 5-ml sterilization solution (2.5 ml 10% Sodium hypochlorite and 2.5 µl Tween 20, made up to 50 ml with sterile MilliQ water). This was done twice with gentle vortex for about 1 min each time.

The seeds were again washed with sterile MilliQ water (vortex and decantation, 4 times). After that, the seeds were put in sterile Petri dishes and dried in clean bench. Dehusked seeds and husks were put in different tubes. One ml wash solution (1.64 g/L $Na_2HPO_4.7H_2O$, 0.28g/L $NaH_2PO_4.2H_2O$, 8 g/L NaCl, 0.05% Tween 80 for making up to 100 ml) was then added and vortex vigorously for 30 sec. As much as possible, the supernatant (regarded as bacterial suspension) was taken with a pipette into a new tube. The supernatant was then centrifuged at 15,000 rpm at 4°C for 10 min. The supernatant was then discarded and 100 µl of DNA extraction solution (0.2 ml 1 M Tris-HCl (pH8.0), 0.1 ml 500 mM EDTA (pH8.0), 1.33 ml 3 M NaCl, 3.03 ml 10% SDS, 2 mg proteinase K, made up to 10 ml with sterile MilliQ water and filter-sterilized with 0.45-um filter in clean bench) added. This was then followed by incubation at 55°C for one hour.

2.2 16S rRNA Gene Amplification

Partial 16SrRNA gene amplification was done using Denaturing Gradient Gel Electrophoresis (DGGE) primers, namely 16S-DGGE-338-F CGCCCGCCGCGCGCGGCGGGCGGGGCGGGGGCACGGGGGGACTCCTACGGGAGGCAGCAG and 16S-DGGE-r517-534 ATTACCGCGGCTGCTGG. The PCR mixture was composed of; 25 µl 2 x AmpDirect Plus, 0.25 µl NovaTaq ™ Hot Start DNApolymerase, 2.5 µl of each primer (12.5 pmol/µl), 18.75 µl sterile MilliQ water and 2 µl sample DNA. Gel electrophoresis was done using 2% gel and 0.5 µg/µl GeneRuler 100 bp DNA ladder Plus marker.

2.3 Denaturing Gradient Gel Electrophoresis (DGGE)

DGGE gel was made by combing two solutions containing acrylamide (structural material) and differing percentages of denaturants (urea and formamide) to form a gradient of denaturant in which double stranded DNA fragments of differing sequence are denatured during electrophoresis. Lambda EcoT14I and GeneRuler 100 bp DNA ladder Plus were used as markers. After electrophoresis, the gel was soaked with 50 ml of 1xSYBR Green/milliQ water and stained for 30 min. The staining solution was then discarded and gel put onto UV illuminator to reveal the different DNA bands. The bands were then excised from the gel using a sterile blade. Each gel slice was put into a clean tube and washed with sterile MilliQ water. Every gel slice was then stored in 50 µl of TE buffer at -20°C.

2.4 Re-amplification of the Bands

The gel slice was crushed in the tube with a pipette tip. One µl of the solution was then used as PCR template. The reaction mixture for the PCR was as following; 0.1 µl Ex Taq DNA polymerase, 2 µl dNTP, 2.5 µl Ex Taq DNA polymerase buffer, 1 µl F338 and R517 primers (10 pmol/µl) and 17.4 µl sterile MilliQ water. Gel electrophoresis was done using 2% gel and 0.5 µg/µl GeneRuler 100bp DNA ladder Plus marker.

2.5 DNA Sequencing

The ca 200-bp rDNA amplicon were subjected to DNA sequencing using 16S-DGGE-338-F and 16S-DGGE-r517-534 ATTACCGCGGCTGCTGG primers. The reaction mixture composed of 1.5 µl BigDye Ready Reaction Mix, 2.5 µl sequencing buffer (5x), 2 µl of 0.9 pmol/µl DGGE primers (16S-DGGE-338-F and 16S-DGGE-r517-534 [separately]), 3.5 µl sterile MilliQ water and 0.5 µl template DNA (Mag Extractor - purified PCR product).

2.6 Processing and Analyzing of DNA Sequences

Obtained sequences were processed using the Staden Package software and BIOEDIT sequence alignment editor. Assembled sequences were analyzed at the Ribosomal Database Project site

(http://rdp.cme.msu.edu/). Phylogenetic analysis was done using the Molecular Evolutionary Genetics Analysis (MEGA) software (http://www.megasoftware.net/).

3.0 Results

3.1 16SrRNA Gene Amplification and Electrophoresis

Endophytic bacterial gene fragments from five samples of rice seed varieties were successfully amplified (Figure 1). Amplified DNA was then subjected to DGGE and a total of 41 DNA bands were excised from the gel (Figure 2).

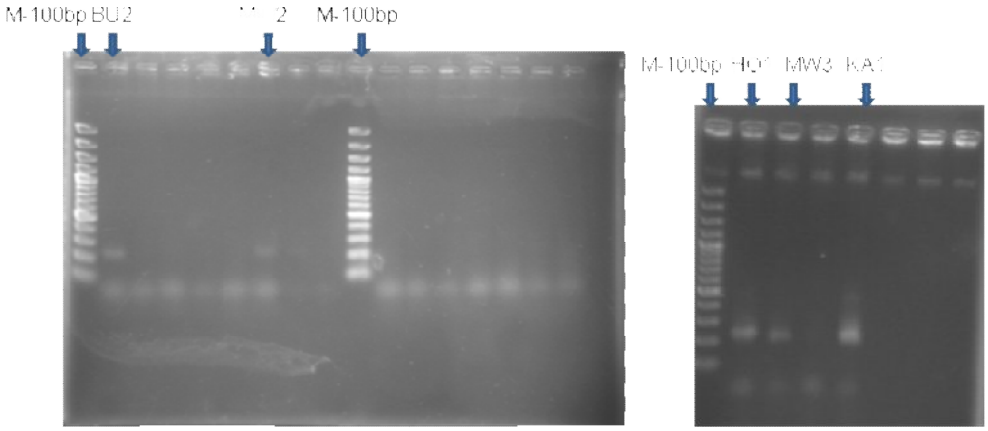


Figure 1: Amplified endophytic bacterial gene fragments from five rice seed varieties. A total of 18 rice seed varieties were processed but only five rice seed varieties yielded visible gene fragments

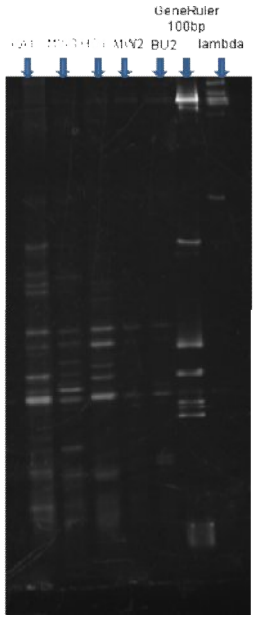


Figure 2: DNA bands of five rice seed varieties after DGGE

3.2 DNA Re-amplification and Sequencing

The excised DNA bands were re-amplified and 31 out of the 41 PCR products obtained were sequenced for endophytic bacteria identification. Table 1 below summarizes the probable endophytic bacteria composition of the five rice seed varieties examined.

Table 1: Probable endophytic bacteria composition of five rice seed varieties determined through DGGE

Variety code	Rice variety	Source	Probable endophytic bacteria composition
KA1	Sigae nyeupe 1	Kaloleni	*Enterobacteriaceae "Enterobacter", Enterobacteriaceae "Pantoea",* & *Sphingomonadaceae "Sphingomonas".*
MW3	2793 - 80-1	Mwea	*Enterobacteriaceae "Pantoea", Pseudomonadaceae "Pseudomonas", Sphingomonadaceae "Sphingomonas" Rhizobiaceae "Rhizobium"* & *Flavobacteriaceae "Chryseobacterium".*
HO1	Sindano bahari	Hola	*Enterobacteriace "Enterobacter"* & *Pseudomonadaceae "Pseudomonas".*
MW2	NERICA 4	Mwea	*Pseudomonadaceae "Pseudomonas".*
BU2	ITA 310	Bunyala	*Methylobacteriaceae "Methylobacterium", Sphingomonadaceae "Sphingomonas"* & *Pseudomonadaceae "Pseudomonas".*

4.0 Discussion and Conclusions

The putative endophytic bacteria detected in the five rice seed varieties examined (Table 1) match with some of those that other researchers have found inside rice plants (Hironobu and Morisaki, 2008). *Pantoea, Pseudomonas, Enterobacter, Sphingomonas* and *Rhizobium* are among the nitrogen-fixing endophytes that have been isolated from rice plants by use of nitrogen-free medium. On the other hand, *Methylobacterium* have been shown to stimulate seed germination and plant development, perhaps through production of phytohormones and in particular cytokinin (Holland *et al*., 2002). There is therefore potential in exploration of the above endophytes for use as biological fertilizers in the production of rice in Kenya.

As expected varietal differences exhibited endophytic bacterial diversity with MW3 having the largest diversity and MW2 the least. Both MW3 and MW2 were sourced from the same geographical region indicating that endophytic bacterial diversity is more host dependent than geographical region dependent. The data available is however not sufficient to support this conclusion. Out of 18 rice seed varieties processed for endophytic bacteria DNA isolation and amplification only 5 yielded visible gene fragments. Further research is therefore recommended in the DNA isolation and amplification in order to optimize on gene fragment yield.

In conclusion, the study achieved its overall object of determining endophytic bacteria composition of rice seeds using a culture-indipendent method namely DGGE. The next level of this study will be to isolate specific bacterial strains and determine their agronomic importance on rice production in Kenya.

Acknowledgements
The authors wish to thank the Research, Production and Extension Division of JKUAT and the JSPS-AASPP program, Japan for sponsoring this study; the National Irrigation Board and farmers from Hola, Kaloleni, Msabweni and Taveta for their facilitation in the acquisition of rice seeds; and the Institute of Plant Science and Resources, Okayama University for hosting the study.

References

Export Processing Zones Authority (2005) Rice sub-sector in Kenya. Pg.2 & 7 in Grain production in Kenya report 2005.

Hallmann, J., Quadt-Hallmann, A. Mahaffee, W. F. and Kleopper, J. W. (1997). Bacterial endophytes in agricultural crops. *Can J Microbiol,.* **43**, pp 895–914.

Holland, M. A., Long, R.L.G. and Polacco J. C. (2002). Methylobacterium spp.: phylloplane bacteria involved in cross-talk with the plant host?, p. 125-135. **In** S.E. Lindow, E.I. Hecht-Poinar, and V.J. Elliot (ed), *Phyllosphere microbiology*, APS Press, St. Paul, Minn.

Long, H. H., Schmidt D. D. and Baldwin I. T. (2008). Native Bacterial Endophytes Promote Host Growth in a Species-Specific Manner; Phytohormone Manipulations Do Not Result in Common Growth Responses, PLoS ONE 3(7): e2702. doi:10.1371/journal.pone.0002702. 2009.

Mano H. and H. Morisaki (2008). Endophytic Bacteria in the Rice Plant. *Microbes Environ*. vol. **23**(2), pp 109-117.

MoA (2009). National Rice Development Strategic Plan (2008 – 2018). Pg. 2.
Tan, R. X. and W. X. Zou (2001). Endophytes: a rich source of functional metabolites. NPR web article.

Torsvik, V., Goksoyr, J. and Daae, F. L. (1990). High diversity in DNA of soil bacteria. *Appl. Environ*., **56** pp 782-787.

THE INFLUENCE OF FERTILIZER PLACEMENT ON MAIZE YIELD AND GROWTH OF WEEDS

A. B. Mashingaidze[1], L. A. P. Lotz[2], W. van der Werf[3], J. Chipomho[4], M. J. Kropff[5] and J. Nabwami[6]

[1,4]Crop Science Department, University of Zimbabwe, Mount Pleasant, Harare, Zimbabwe

[2]Plant Research International, Wageningen, The Netherlands

[3,5]Wageningen University, Department of Plant Sciences, Group Crop and Weed Ecology, Wageningen, The Netherlands

E-mail: abmash@yahoo.com

Abstract

Three field experiments were conducted in two seasons in Zimbabwe to study the effects of rate and method of placement of NPK fertilizer on productivity of maize and the emergence and growth of weeds. Compound D (8% N, 14% K_2O, 7% P_2O_5, 6,5% S) was applied at 75, 150 and 225 kg ha^{-1} using three placement methods *viz*. spot placement, banding and broadcasting in Experiment 1. The three placement methods were combined with four weed-free period and weedy periods in Experiment 2 and 3. Maize yield was highest at 150 kg ha^{-1} of compound D in Experiment 1. Banding consistently attained the highest maize grain yield, followed by spot placement and broadcasting. Early maize growth and grain yield data suggested that spot placement may reduce the yield response of the maize to fertilizer in water limited environments by predisposing maize plants to higher levels of moisture stress, when compared to banding. Spot and band placement increased radiation interception and early growth of maize and reduced the emergence, growth and seed production of weeds, compared to broadcasting; however the effects of fertilizer placement on weeds did not significantly affect the duration of critical period for weed control required to avert yield loss in maize. Our results suggest that smallholder farmers may maximize the benefits, of increased yield and suppression of weeds, derived from scarce fertilizer/manure resources by using precise methods of placement, more so with banding than spot placement.

Key words: Fertilizer, placement method, maize growth, maize grain yield, radiation interception, weed density, weed biomass, weed seed production

1.0 Introduction

Weed control is the dominant labour demanding occupation of smallholder farmers in semi-arid regions of Africa during the cropping season (Akobundu, 1991). Farmers invest large amounts of labour in weeding each season, approximately 35 to 70% of the total agricultural labour needed to produce crops which frequently exceeds the labour demand of all other livelihood operations for smallholder farmers. Severe labour bottlenecks are common during peak weeding, resulting in delayed weeding in large portions of the planted crops, well after they have suffered significant damage from weeds (Waddington and Karigwindi, 1996).

A paradigm shift from weed control to weed management is required to effectively address the problems caused by weeds for smallholder farmers. Weed control emphasizing the control of existing weed problems is a curative approach that produces short-term results but may create or worsen long-term problems (Buhler, 1999). Weed management places greater attention on the prevention of propagule production, reduction of weed emergence in a crop and minimizing weed interference with the crop through the integration of techniques, knowledge and management skills (Buhler, 1999; Zimdahl, 1991). Cultural weed management techniques such as narrow planting, use of competitive crop varieties, mixed cropping and precise placement of fertilizers and manures have potential to reduce emergence, growth and competitiveness of weeds (Swanton and Wiese, 1991).

The weed competition dynamics for applied fertilizer nutrients can be changed in favour of the crop by the method of placement of the fertilizer (Blackshaw *et al*., 2002). Fertilizer placement in narrow bands below the soil surface in the crop row has been found to reduce the competitive ability of weeds compared to broadcast placement of fertilizer (Blackshaw *et al*., 2000, 2002; Kirkland and Beckie, 1998; Mesbar and Miller, 1999). In the context of smallholder agriculture in semi-arid areas, fertilizer is a scarce and expensive resource whose benefits must be maximized by precisely placing it in the root zone of the crop. Most smallholder farmers cannot afford to apply the recommended fertilizer application rates and frequently apply 30-50% of the recommended application rates (Chivinge and Mariga, 1998). Previous research on fertilizer placement methods in Zimbabwe has concentrated on nutrient uptake and early growth by the crop without a concomitant look at the weed crop competition dynamics (Tanner, 1984). No studies have been done in Zimbabwe to optimize fertilizer practices combined with reducing weed emergence and growth in the crop (Chivinge and Mariga, 1998).

The objective of this study was to determine the effect of fertilizer rate of application and placement methods on weed emergence and growth of weeds, early growth, radiation interception and yield of the maize crop. Hypotheses tested were (a) precise placement of fertilizer will increase early growth, radiation interception by the maize crop and reduce weed emergence and growth (b) precise placement of fertilizer will reduce the weed-free period required to avert yield loss in maize.

2.0 Materials and Methods

Experiment 1 was carried out at the University of Zimbabwe campus in the 2001/02 season and Experiments 2 and 3 at the Rio Tinto Agricultural College in the 2002/03 season. The University of Zimbabwe campus site in Harare (17°50′ South and 31°30′ East, altitude of 1500 m), has red fersiallitic clay soils (30-40% clay) with an annual rainfall of 600-800 mm. received between. Growing season (November-May) temperatures range from 20 to 25 °C. The Rio Tinto Agricultural College site (29°30′ East and 19°20′ South) lies in the Zhombe district, in the rain shadow area of the Mapfungautsi plateau in the middle of Zimbabwe. The site is characterized by sandy clay loams of shallow depth (30 cm), derived from granite and dolorite parent material. Growing season temperatures are fairly high, on average about 30 °C. Frequent mid season droughts characterize the rainy season and total seasonal

rainfall is 450 - 600 mm.. For the crop to be carried through the season supplementary irrigation was needed at the Rio Tinto site. For all the three experiments, the land was ploughed and planting was done in last quarter of November after the first effective rains.

Experiment 1: Rate and placement method of fertilizer

Experiment 1 was set up as a 3 × 3 factorial to determine the effect of fertilizer application rates and placement methods on the emergence and growth of weeds, early growth and maize grain yield.. It was laid out as a randomized complete block design with three replicates. Fertilizer application rates were 75, 150 and 225 kg ha^{-1} of basal granular compound D fertilizer (8% N, 14% P_2O_5, 7% K_2O, 6.5% S). Fertilizer placement methods were spot placement, banding and broadcasting. Spot placement was achieved by placing the fertilizer into an opened planting station of about 5 cm depth. Banding was achieved by opening planting furrows approximately 5 cm deep using hoes and dribbling the required fertilizer in along the planting furrow, as evenly as possible, by hand. Broadcasting was achieved by evenly spreading the fertilizer onto the plot and incorporating it to 5-10 cm depth using hoes. Maize was planted at 90 cm × 30 cm spacing to achieve a density of 37,000 plants ha^{-1}. Two maize seeds were placed into each planting station and covered. Maize plants were thinned to one plant per station, two weeks after crop emergence (WAE). A short season three-way cross hybrid, SC 513 (Seed-Co®, Zimbabwe) was planted.

Weeds were counted at 5 and 8 WAE in three randomly placed 30 cm × 30 cm quadrats each, at two positions, in the maize row and in the middle of the maize inter-row. Counted weeds were cut at the ground level, oven-dried at 80 °C for 48 hours and weighed.

Four maize plants were randomly selected per plot (outside the net plot) at 5 WAE and used for leaf number, plant height and biomass determination. The gross plot was 4.5 m × 7 m with 5 maize rows. The net plot was 2.7 m × 5.0 m.

Photosynthetically active radiation (PAR) incident above the crop, at mid crop height and on the ground was measured at 8WAE using 191-SA line quantum sensors (Li-Cor, Lincoln, Nebraska, USA). Measurements were taken at two positions, in the row (adjacent to the maize stems along the maize row) and between rows (in the centre of the inter-row). Three replicate measurements were taken at 2, 4 and 6 m along the maize row in the net plot. The average PAR measurement for the three positions was used in the data analysis. Maize was hand harvested from the net plot, shelled by hand and moisture content measured. Grain yield was standardized to 12.5% moisture content.

Experiments 2 and 3: Fertilizer placement methods and the weedy/weed-free period

Experiments 2 and 3 were designed to study the effect of fertilizer placement method and different weed-free (Experiment 2) or weedy (Experiment 3) periods on maize yield and the emergence, growth and seed production of weeds. In both experiments, the fertilizer placement methods were spot placement, banding and broadcasting as described for Experiment 1. In both experiments, a 3 x 4 factorial design was used to study the combined effects of fertilizer placement method and weeding. In Experiment 2, four different weed-free period were tested: 3, 6, 9 and 12 weeks after emergence of the crop. After the required weed-free period, the crop was left unweeded. In experiment 3, four different weedy periods were compared; also 3, 6, 9, and 12 weeks. The crop was kept weed free after the weedy period was finished. Both experiments were laid out as randomized complete block designs with three replicates. One fertilizer application rate, 150 kg of compound D was used. Experiment 3 was planted at the same time and adjacent to Experiment 2.

PAR measurements were conducted as in Experiment 1, at 2 and 4 WAE. Maize early growth was assessed on five randomly selected maize plants which were harvested from outside the net plot area at 3 and 6 WAE. Maize height was measured using a tape measure from the ground to the tip of the maize funnel. Leaf area was measured using a LA-3100 leaf area meter (Li-Cor, Lincoln, Nebraska, USA). The maize plants were oven dried to a constant weight and weighed. Weed density and dry mass were determined as in Experiment 1, at 3, 6 and 9 WAE, before the weeding treatments scheduled for that time were implemented. Weed seed capsules were counted for the major species of weeds, as indicated by visual assessment of percent ground cover at maize physiological maturity at 15 WAE.

Maize was hand harvested from the net plots at 20 WAE and moisture content of shelled grain measured. A random sample of five cobs was taken from each plot and ear length, ear mass, number of kernel rows ear^{-1} and of kernels row determined.

Data Analysis

All weed density and weed seed capsule data were expressed m^{-2} and $\sqrt{x+0.5}$ transformed before statistical analysis (Steel and Torrie, 1984). In all experiments, maize grain yield was standardized to 12.5% moisture content. Data were analyzed by ANOVA using SAS Version 8 (SAS Institute 1999, Release 8, Cary, NC, USA). Means were separated using Fisher's Least significant difference (Lsd) at P< 0.05. Standard errors of the difference are shown for all figures.

3.0 Results

3.1 Growth and Yield of Maize

Maize grain yield in Experiment 1 increased by 30% when fertilizer application rate was increased from 75 to 150 kg ha^{-1} but decreased on further increasing the fertilizer rate to 225 kg ha^{-1} (Table 1). Plant dry weight varied from 18.3, 20.2 to 19.0 g plant^{-1} and plant weight from 65, 74 to 70 plant^{-1} as fertilizer rate was increased from 75, 150 to 225 kg ha^{-1}, respectively, but the effect of fertilizer rate was not significant (P > 0.05) on these two factors. Only number of leaves plant^{-1} was significantly affected (P < 0.05) by fertilizer rate. The intermediate (8.6 leaves plant^{-1}) and highest (8.1 leaves plant^{-1}) fertilizer level had significantly higher number of leaves than the lowest (7.4 leaves plant^{-1}) fertilizer rate ($Lsd_{0.0}$ = 0.93, n = 9). Maize grain yield was higher in the banded fertilizer placement treatment than in the broadcast placement treatment at all fertilizer application rates, however, the overall effect of fertilizer placement was not different (P > 0.05) in Experiment 1 (Table 1). Fertilizer placement did not significantly affect leaf number and plant dry weight, but plant height was significantly lowered when fertilizer was broadcast (62 cm plant^{-1}) rather than banded (72 cm plant^{-1}) or spot-applied (74 cm plant^{-1}) ($Lsd_{0.05}$ = 10.05, n = 9).

Maintaining the crop weed-free for the first three weeks achieved 74, 86 and 87% of the maximum grain yield in the spot, band and broadcast treatments, respectively, in Experiment 2 (Fig. 1a). Keeping the crop longer weed free for more than 3 weeks did not result in further yield increase (Fig. 1a). Fertilizer placement did not affect the grain yield response to increasing the weed-free period as indicated by an insignificant fertilizer placement $\times$ weed-free period interaction (P>0.05). The banded treatment produced significantly higher maize grain yield than the broadcast treatment, averaged across the weed-free period treatments (P<0.05). The maize grain yield from the spot placed fertilizer treatment was intermediate between the banded and broadcast fertilizer placement treatments and did not differ significantly from either treatment (Fig. 1a). Plant height, biomass and LAI were lower upon broadcasting than with the other two placement methods in Experiment 2 (Fig. 2).

In Experiment 3, the fertilizer placement method ($P<0.01$) and the duration of the weedy period ($P<0.001$), both had a significant influence on maize grain yield. The two factors did not significantly interact indicating that yield response to weeding delay was similar in the three fertilizer placement methods (Fig. 1b). The banding of fertilizer produced higher maize grain yield than spot and broadcast placement methods, averaged across the weedy periods (Fig. 1b). Plants in the broadcasting treatment lagged behind those in the other two placement treatments in height, weight and leaf area (results not shown).

3.2Maize Grain Yield Components

There were no significant fertilizer placement $\times$ weed-free/weedy period interactions in any of the maize grain yield components and, therefore, the main effects are presented. Table 4 shows the effects of fertilizer placement on maize yield components in Experiments 2 and 3. Spot and band placement of fertilizer resulted in significantly bigger ears (ear length and ear mass) than broadcasting in Experiment 2. In Experiment 3, all yield components increased from broadcasting to spot and band placement treatments, respectively (Table 4).

Increasing the duration of the weed-free period beyond three weeks did not significantly enhance maize yield components in Experiment 2 (Table 5). Increasing the duration of the weedy period reduced all grain yield components except number of kernel rows ear^{-1} in Experiment 3 (Table 5).

3.3Weed Density and Biomass

In experiment 1, weed density as determined at 5 WAE was not significantly affected by fertilizer placement or rate of application. At 8 WAE, one significant difference was found between the density of weeds between the rows in the broadcast (6.6 m^{-2}) compared to the banding (5.88 m^{-2}) placement method ($Lsd_{0.05}$ = 0.657; n = 9). No other significant differences were found. There was a significant interaction ($P < 0.01$) between fertilizer placement method and rate of application on weed biomass within the maize row at 5 WAE (Table 6). The biomass of weeds within the row decreased in the broadcast treatment with increased quantity of fertilizer applied. With spot and band placement methods of fertilizer application, the weed biomass increased in the row with increased quantity of fertilizer applied (Table 6).

In Experiment 2, there was a consistently higher weed density and biomass in the broadcast compared to the spot and band fertilizer placement treatments (Figs 4a and 4b). In Experiment 3, weed density tended not to statistically differ between the banding and broadcasting treatments with spot placement having the lowest weed density at 3, 6 and 9 WAE (Figure 4c).

There was a fertilizer placement method $\times$ weed free period interaction on weed biomass in Experiment 2. It required a weed free period of 6 WAE for the broadcast treatment to attain the same weed biomass as the spot and band placement treatments with a weed free period of 3 WAE (data not shown).

A higher weed density and biomass were measured within the rows than between the rows in Experiment 2 (Figures 5a and 5b). In Experiment 3, there was an interaction ($P < 0.05$) between fertilizer placement and sampling position on weed density at 3 WAE. Broadcasting the fertilizer produced the same weed density in the row and in the middle of the inter-row, while more weeds emerged in the row compared to the middle of the inter-row in the spot and band fertilizer placement methods (Figure 5c).

3.4 Seed Production by Weeds

A significantly higher number of weed seed capsules were counted in the broadcast compared to the spot and band fertilizer placement methods for *Commelina benghalensis* L.*, Amaranthus hybridus* L. and all species (Figure 6a). For all species, a 9 week weed-free period was required to completely stop the addition of weeds to the seedbank (Fig. 6b). For *C. benghalensis*, there was a significant interaction between fertilizer placement method and weed-free period on its seed production. For the band and spot fertilizer placement methods, a weed-free period of 6 WAE was adequate to almost stop weed seed capsule production, while the same weed-free period in the broadcast treatment only resulted in a 20% reduction of seed capsule production (Figure 7a). A weed-free period of 9 WAE was required to stop additions of new seed by *C. benghalensis* to the seedbank in the broadcast treatment (Figure 7a). Weed seed production was nil in all the weeded treatments at 15 WAE, but in the unweeded treatment, seed capsule production decreased from broadcast, spot to band fertilizer placement method (Figure 7b).

3.5 Radiation Interception

There was no significant effect of fertilizer placement method on PAR reaching the ground in Experiment 1. PAR reaching the ground was significantly lower ($P < 0.05$) in 150 kg (1257 µmols m^{-2}) than at 75 kg (1444 µmols m^{-2}) and did not differ with the 225 kg ha-1 (1336 µmol m^{-2}) meaning that radiation interception was significantly higher at 150 kg than the 75 kg ha^{-1} fertilizer application rate at 8 WAE in Experiment 1. Percent of total PAR intercepted at 4 WAE was significantly higher ($P < 0.01$) in the spot (67.4%) and band (66.9%) fertilizer placement treatments than in the broadcast treatment (34.6%) in the middle of the row in Experiment 2. The unweeded treatments at 4 WAE intercepted 78% of the incoming radiation compared to 56.4% in the middle of the row than the treatments kept weed-free from 3 weeks onwards in Experiment 3, such that no differences could be detected among the three fertilizer placement methods in Experiment 3.

4.0 Discussion

4.1 Maize Grain Yield

The results of this study show that by promoting higher rates of early growth and concomitantly earlier attainment of full ground cover, precise methods of fertilizer placement (spot placement and banding) increased the competitiveness of the crop against weeds, significantly reducing weed density, biomass and seed production and increased crop yields when compared to broadcasting. The banding treatment consistently attained the highest maize grain yield, followed by spot placement, and broadcasting attained the lowest, during the three experiments of this study. Our results also suggest that spot placement maybe risky in water limited environments, where the high concentration of the fertilizer around the root zone the crop may predispose the crop to higher levels of moisture stress and reduce the growth and yield response to the applied fertilizer. Banding of fertilizers below or on the side of the crop row in the soil has been shown not only to reduce weed populations but also to increase crop yields when compared to broadcasting in beans (*Phaseolus vulgaris* L.) (Ottabong *et al*., 1991), soybean (*Glycine max* Merr.) groundnuts (*Arachis hypogaea* L.) (Everaarts, 1992) and wheat (*Triticum aestivum* L.) (Cochran *et al*., 1990). The banding of fertilizer below the seed or to one side of the seed concentrates mineral nutrients in the root zone of the crop. It also restricts access of weeds to the fertilizer by spatial separation and by virtue of the shallow depth of soil exploited by most annual weed roots (DiTomasi, 1995; Ottabong *et al*., 1991; Moody, 1981). Nitrogen uptake and biomass of weeds was lower and wheat yields higher with sub-surface banded or point injected N fertilizer compared to surface broadcast (Blackshaw *et al*., 2004, 2005; O'Donovan *et al*., 2007).

Early growth of the maize in the banding and spot placement treatments was generally greater than in the broadcast treatment, agreeing with results of Tanner (1984), in an experiment on similar soils as in Experiments 2 and 3. However, in all cases in this study, the trend in maize grain yield showed a consistent superiority of banding over spot placement, albeit not statistically significant in Experiments 1. These results may be indicative of the droughty conditions that characterized the two seasons in which these experiments were held. Tanner (1984) explained that spot placement maybe more beneficial in seasons with adequate rainfall than banding and broadcasting but the opposite can be true in dry seasons as high concentrations of fertilizer around the root zone of the crop where fertilizer has been spot placed increases the severity of moisture stress episodes much more than in the broadcast and band treatments. The apparent superior maize grain yield of the banding treatment over the spot placement treatment may be attributable to this phenomenon. This should hold given rainfall totals of 667 mm in 2001/02 season at UZ campus and 450 mm in the 2002/03 season at Rio Tinto, and the fact that rainfall was poorly distributed within the season, at both sites.

To some extent the results of the rate of fertilizer application on maize grain yield in Experiment 1 lend support to the hypothesis that high concentrations of fertilizer were somewhat damaging to maize grain yield. Maize grain yield showed a distinct trend of decreasing from the 150 to the 225 kg ha^{-1} application rate, more so in the spot than in the band fertilizer placement treatments and no response in the broadcast treatment (Table 1). Early maize growth data also displayed similar trends (Table 1). These results suggest that at 225 kg ha^{-1} of compound D fertilizer, the high concentrations of fertilizer in the root zone of the spot and band placed fertilizer probably predisposed the plants to more severe episodes of drought stress.

Broadcasting of fertilizer and its incorporation into the soil mean that the applied mineral nutrients will be distributed more or less uniformly across the soil surface and in the soil depth to which the fertilizer is incorporated. In contrast, with spot and band placement of fertilizer, the fertilizer is placed below the soil surface nearest to the root zone of the crop. The dormancy of some annual weed species is broken by increased levels of nitrates in the soil (DiTomasi, 1995; Agenbag and De Villiers, 1989) and this may explain the higher densities of weeds observed in the broadcasting treatment compared to banding and spot placement treatments. Banding of fertilizer reduced weed density compared to broadcasting in a number of studies (Ottabong *et al*., 1991; Everaarts, 1992; Cochran *et al*., 1990; Kirkland and Beckie, 1998) similar to our results. It would seem, therefore, that weeds tend to emerge in greater number where fertilizers are spread and incorporated throughout the whole soil surface in comparison to more precise placement of fertilizer nearest the crop roots.

Access to applied fertilizer nutrients is promoted for the crop and restricted for the majority of the shallow rooted weeds found in the mid-row area when fertilizer is banded or spot placed nearest the crop seed at planting. The opposite would be true when fertilizer is broadcast and incorporated in the soil. This would explain why higher weed biomass was recorded from the broadcast compared to the spot and band fertilizer placement treatments in this study. Higher levels of nutrient uptake by weeds have been recorded when fertilizer was broadcast compared to more precise fertilizer placement methods into the soil nearest to the crop rooting zone (Blackshaw *et al*., 2002). To some extent this may partly explain the higher rates of growth of weeds in the broadcast treatments recorded in this study and others in the literature. Kirkland and Beckie (1998) reported that broadcast applied fertilizer was more effective than banded fertilizer in promoting wild oat and broadleaf weed emergence and growth over the season in a wheat crop. Weeds are generally more efficient in accumulating soil nutrients than crop plants (Vengris *et al*., 1953; Sibuga and Bandeen, 1980, Moody, 1981; Teyker *et al*., 1991; DiTomasi, 1995; Qusem, 1992, 1993; Ampong-Nyarko and De Datta, 1993;). It is, therefore, expected that weeds

will win the competition battle with the crop for applied fertilizer nutrients unless access to the nutrients promoted for the crop and discouraged for weeds by precise placement of the fertilizer.

The effects of precise fertilizer placement in denying access of weeds to applied nutrients and, therefore, reducing the competitiveness of weeds against the crop is confounded with its effects in promoting higher rates of crop growth and attainment of earlier canopy closure which achieve the same effect. Results of this study generally showed that band and spot placement of fertilizer increased early maize growth and PAR interception compared to maize grown in the broadcast treatment. Competition for light tends to give an increasing advantage to the plants that have a starting position advantage (bigger and leafier plants at the start of the dynamic process of competition). Weiner *et al*. (1997) observed that larger plants were able to obtain a share of resources that was disproportionate to their relative size and to suppress the growth of smaller individuals. The lower weed biomass attained by weeds in the spot and band placed fertilizer treatments compared to the broadcast treatment in this study is, therefore, partly explainable in terms of these placement methods increasing the size and competitiveness of the maize crop against weeds.

Our results also show that there is likely to be increased weed growth within the row when fertilizer is spot or band placed compared to broadcasting and such weed growth may increase in the row with increased rates of fertilizer application. Munguri (1996) reported similar results in sandy soils. It may, therefore, mean that fertilizer placement should be integrated with weed management tactics that remove weeds within the row soon after crop emergence before they cause crop damage. Weeds that are within the row are nearest to crop plants and if they grow together with the crop, are more damaging than those in the middle of the row especially early on, soon after crop emergence.

The lower seed production by weeds in the band and spot fertilizer placement treatments compared to the broadcast treatments is reflective of the linear relationship between weed biomass and fecundity of annual weeds found in other studies (Thompson *et al*., 1991). The reduction in seed production with precise placement of fertilizer compared with broadcasting means that these methods will not only be potentially beneficially in increasing crop yields and reducing weed competition, but could affect weed propagule numbers in the soil seedbank in the long term.

Results of this study show that the maize crop must be weeded at 3 WAE to achieve maximum yields and that there is no yield advantage to be gained by continuing to weed the crop after 6 WAE. Tanveer *et al*. (2001) found similar results when they tested the effect of weed free periods with side-placement and broadcasting of fertilizer in wheat. These results were consistent for all fertilizer placement methods as there were no interactions between the fertilizer placement methods and weed-free/weedy period in Experiments 2 and 3. It would seem, therefore, that although weed density and biomass were reduced by precise placement of fertilizer in the rooting zone of the crop, the reduction in weed competitiveness was not adequate to effectively reduce the overall weeding requirements of the crop for attainment of maximum yields.

Increased precision in the placement of fertilizer nearest to the rooting zone of the crop had been shown to enhance the competitiveness of the crop against weeds in this study. Weed emergence and growth were reduced and crop growth was enhanced significantly more in the banding and spot placement methods than in the broadcast method of fertilizer application. For smallholder farmers, precise placement of fertilizer makes sure that the little fertilizer that is applied literally ‘goes a long way’ because it produces yields that are similar to those that are obtained with higher fertilizer application rates applied using the broadcasting method (Jonga *et al*., 1996; Munguri, 1996). Chivinge

and Mariga (1998) showed that half the recommended fertilizer application rates (44 kg N ha^{-1}) produced maize grain yield similar or higher than full application rates provided that adequate weed control (hoe-weeding at 3 and 5 WAE or application of 1.75 kg a.i. atrazine full cover spray) was carried out in the smallholder sector in a semi-arid area of Zimbabwe. Munguri (1996) showed that the same similar benefits were derived when fertilizer or manure was banded or spot placed in comparison to broadcasting, meaning that precision of placement technology is also available to those farmers with cattle and access to cattle manure.

systems from two fronts, reduced weed competitiveness and increased crop yield, more with band than spot application, in water limited environments, as suggested by results of this study. Our results seem to indicate that high fertilizer application rates and/or spot placement of fertilizer may nullify any expected yield gains from the supply of mineral nutrients by a greater predisposition of the crop to moisture stress in semi-arid regions. The fertilizer placement decisions must, therefore, take into account the soil moisture conditions that are likely to prevail in the particular semi-arid environment, however banding gave consistently high yields in water limited environments in this study.

References

Agenbag, G. A. and De Villiers, O. T. (1989). The effect of nitrogen fertilizers and seedling emergence of wild oat (*A. fatua* L.) seed in different soil types. *Weed Research,* **29**, PP 239-245.

Akobundu, I. O. (1991). Weeds in human affairs: Implications for sustainable food production. *Weed Technology,* **5**, pp 680-690.

Ampong-Nyarko, K. and De Datta, S. K. (1993). Effects of nitrogen application on growth, nitrogen use efficiency and rice-weed interaction. *Weed Research,* **33**, pp 269-276.

Blackshaw, R. E., Semach, G. Li, X. O'Donovan, J. T and Harker, K. N. (2000). Tillage, fertilizer and glyphosate timing effects on foxtail barley (*Hordeum jubatum*) management in wheat. *Canadian Journal of Plant Science,* **80**, pp 655-660.

Blackshaw, R. E., Semach, G. and Janzen, J. H. (2002). Fertilizer application method affects nitrogen uptake in weeds and wheat. *Weed Science,* **50**, pp 634-641.

Blackshaw, R. E., Molnar L. J. And Janzen H. H. (2004). Nitrogen fertilizer timing and application method affect weed growth and competition with spring wheat. *Weed Science*, **52**, pp 614-622.

Blackshaw, R. E., Molnar L. J. and Larney F. J. (2005). Fertilizer, manure and compost effects on weed growth and competition with winter wheat in western Canada. *Crop Protection*, **24**, pp 971-980.

Buhler, D. D. (1999). Expanding the context of weed management. Journal of Crop Production **2**, pp 1-7.
Chivinge, O. A. and Mariga, I. K. (1998). Effect of fertilizer rates and weed management under low input dryland conditions on maize yield. *Crop Research (Hisar),* **15** (1), pp 1-10.

Cochran, V. L., Morrow, L. A. and Schirman, R. D. (1990). The effect of N placement on grass weeds and winter wheat response in three tillage systems. *Soil Tillage Research,* **18**, pp 347-355.

DiTomasi, J. (1995). Approaches for improving crop competitiveness through the manipulation of fertilization strategies. *Weed Science,* **43**, pp 491-497.

O'Donovan, J. T., Blackshaw R. E., Harker K. N., Clayton G. W., Moyer J. R., Dosdall L. M., Naurice D. C. and Turkington T. K. (2007). Integrated approaches to managing weeds in spring sown crops in western Canada. *Crop Protection*, **26**, pp 390-398.

Everaarts, A. P. (1992). Response of weeds to the method of fertilizer application on low- fertility acid soils on Suriname. *Weed Research,* **32**, pp 391-397.

Jonga, M., Mariga I. K., Chivinge O. A., Munguri M. W. and Rupende E. (1996). Towards the improved management of organic and inorganic fertilizers in dryland maize production in the smallholder sector of Zimbabwe. Proceedings of the Maize Productivity Gains Through Research and Technology Dissemination in East and Southern Africa Conference. Arusha, Tanzania, 3-7 June 1976, CIMMYT maize programme. CIMMYT, Mexico DF, pp.202-206.

Kirkland, J. K. and Beckie H. J. (1998). Contribution of nitrogen fertilizer placement to weed management in spring wheat (*Triticum aestivum*). *Weed Technology,* **12**, pp 507-514.

Mesbar, A. O. and Miller, S. D. (1999). Fertilizer placement affects jointed goatgrass (*Aegilops cylindrica*) competition in winter wheat (*Triticum aestivum*). *Weed Technology*, **11**, pp 502-509.

Moody, K. (1981). Weed-fertilizer interactions in rice. *International Rice Paper Series*, **68**, pp 1-35.

Munguri, M. W. (1996). Inorganic fertilizer and cattle manure management for dryland maize production under low input conditions. Master of Philosophy thesis. Crop Science Department, University of Zimbabwe.

Ottabong, E., Izquierdo, M. M. L., Talavera, S. F. T., Geber, U. H. and Ohlander, L. J. R. (1991). Response to P fertilizer of *Phaseolus vulgaris* L. growing with and without weeds in a highly P-fixing mollic Andosol. *Tropical Agriculture,* **68**, pp 339-343.

Qusem, J. R. (1992). Nutrient accumulation by weeds and their associated vegetable crops. *Journal of Horticultural Science,* **67**, pp 189-195.

Qusem, J. R. (1993). Root growth, development and nutrient uptake of tomato (*Lycopersicon esculentum*) and *Chenopodium album*. *Weed Research,* 33, 35-42.

SAS (1999). *SAS Language guide. Release 8.00.* SAS Institute Inc., Cary, USA.

Sibuga, K. P. and Bandeen, J. D. (1980). Effect of various densities of green foxtail (*Setaria viridis* (L.) Beauv.) and lambs quarters (*Chenopodium album* L.) on nitrogen uptake and yields of corn. *East African Agricultural and Forestry Journal,* **45**, pp 214-221.

Steel, R. G. D. and Torrie J. H. (1984). Principles and Procedures of Statistics. 2nd Edition. MacGraw-Hill; New York.

Swanton, C. J. and Wiese, S. F. (1991). Integrated weed management: The rationale and approach. *Weed Technology,* **5**, pp 657-663.

Tanner, P. D. (1984). Effect of method of placement of granular compound on growth, potassium and phosphorus uptake and yield of maize. *Zimbabwe Agricultural Journal,* **81**, pp 3-7.

Tanveer, A., Ahmad, R., Ali, A. and Ayub, M. (2001). Chenopodium album competition with wheat (*Triticum aestivum* L.) in respect to nitrogen and grain yield. *Indian Journal of Agricultural Research,* **35**, pp 232-237.

Teyker, R. H., Hoelzer, H. D. and Liebl, R. A. (1991). Maize and pigweed response to nitrogen supply and form. *Plant and Soil*, **135**, pp 399-406.

Thompson, B. K., Weiner, J. and Warwick, S. I. (1991). Size dependent reproductive output in agricultural weeds. *Canadian Journal of Botany,* **69**, pp 442-446.

Vengris, J., Drake, M., Colby W. G. and Bart, J. (1953). Chemical composition of weeds and accompanying plants. *Agronomy Journal*, **45**, pp 213-218.

Waddington, S. R. and Karigwindi, J. (1996). Grain yield of maize populations and commercial hybrids after competition from weeds early in crop development. *Zimbabwe Journal of Agricultural Research,* **34**, pp 45-54.

Weiner, J., Wright D. B. and Castro, S. (1997). Symmetry of below-ground competition between *Kochio scoparia* individuals. *Oikos,* **79**, pp 85-91.

Zimdahl, R. L. (1991). Weed science: A plea for thought. Washington, DC: United States Department of Agriculture, Cooperative State Research Service.

Table 1: Effect of fertilizer application rate and placement method on maize grain yield (t ha^{-1}) in Experiment 1

	Fertilizer application rates (kg ha^{-1})			
Fertilizer placement method	75	150	225	Mean
Spot	2. 448	3. 686	2. 858	2. 998
Band	3. 107	3. 748	3. 271	3. 376
Broadcast	2. 436	2. 978	3. 077	2. 831
Mean	2.664a[1]	3.471b	3.069ab	

	P value	SED	Lsd $_{0.05}$
Effect of fertilizer rate	P<0.05	0.347	0. 736
Effect of fertilizer placement	P>0.05	0.347	NS
Rate × placement interaction	P>0.05	0.601	NS

[1]Means followed by the same letter in a row are not significantly different at P<0.05

Table 2: Effect of fertilizer placement on maize grain yield components in Experiments 2 and 3

Fertilizer placement	Ear length cm ear^{-1}		Ear mass kg ear^{-1}		Number of kernel rows ear^{-1}		Number of kernels row^{-1}	
	Exp 2	Exp 3	Exp 2	Exp 3	Exp 2	Exp 3	Exp 2	Exp 3
Spot	15.4b[1]	13.8b	0.23b	0.17b	15.0a	14.8a	37.3a	30.6b
Band	16.1b	16.1c	0.25b	0.20c	15.0a	15.3ab	37.8a	34.0c
Broadcast	10.1a	10.0a	0.14a	0.11a	14.7a	15.8b	34.9a	23.8a
P-value	P<0.001	P<0.001	P<0.001	P<0.001	P>0.05	P<0.05	P>0.05	P<0.001
Sed	0.481	0.602	0.016	0.011	0.506	0.355	1.253	1.079
$Lsd_{0.05}$	0.998	1.248	0.033	0.023	NS	0.737	NS	2.239

[1]Means followed by the same letter in a column are not significantly different at P<0.05

Table 3: Effect of weeding regime (weeks after emergence, WAE) on maize grain yield components in Experiments 2[1] and 3[2]

Weeding regime	Ear length cm ear^{-1}		Ear mass Kg ear^{-1}		Number of kernel rows ear^{-1}		Number of kernels row^{-1}	
	Exp2	Exp 3	Exp 2	Exp 3	Exp2	Exp 3	Exp 2	Exp 3
3 WAE	13.8a[3]	15.9c	0.20a	0.22d	15.1a	15.1a	36.0a	33.9c
6 WAE	13.6a	15.0c	0.20a	0.19c	14.9a	15.6a	37.2a	31.6c
9 WAE	14.3a	12.1b	0.23a	0.14b	15.1a	15.3a	37.6a	28.1b
12 WAE	13.8a	10.3a	0.19a	0.10a	14.4a	15.3a	35.9a	24.3a
P-value	P>0.05	P<0.001	P>0.05	P<0.001	P>0.05	P>0.05	P>0.05	P<0.001
Sed	0.556	0.695	0.018	0.013	0.584	0.410	1.447	1.246
$Lsd_{0.05}$	NS	1.441	NS	0.026	NS	NS	NS	2.585

[1] Weeding regime refers to duration of weed free and then weedy period in Experiment 2 in Table 2.
[2] Weeding regime refers to duration of weedy period and then weed free in Experiment 3 in Table 2.
[3]Means followed by the same letter in a column are not significantly different at P < 0.05

Table 4: Interaction between fertilizer application rate and method of placement on weed biomass (g m^{-2}) in the row in Experiment 1

Placement method	Fertilizer applications rates in kg ha^{-1}		
	75	150	225
Spot	16.52a[1]	23.31a	25.32a
Band	16.43a	14.52a	32.54b
Broadcast	30.43b	18.72ab	14.31a

	P-value	Sed	$Lsd_{0.05}$
Effect of fertilizer placement method	P>0.05	3.440	NS
Effect of rate of fertilizer application	P>0.05	3.440	NS
Rate × placement interaction	P<0.01	5.985	12.305

[1] Means followed by the same letter in a row are not significantly different at P < 0.05.

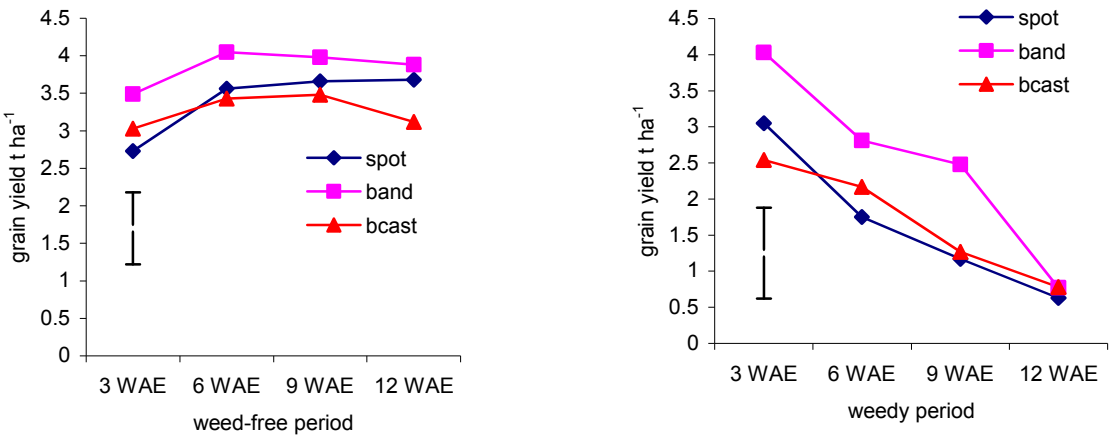


Figure 1: (A) Effect of weed free period (then weedy) and fertilizer placement method on maize grain yield in Experiment 2. (B) Effect of weedy period (then weed-free) and fertilizer placement method on maize grain yield in Experiment 3. Error bars within each figure represent ± standard error of the difference (22df) for the comparison of grain yield means within and between fertilizer placement treatments

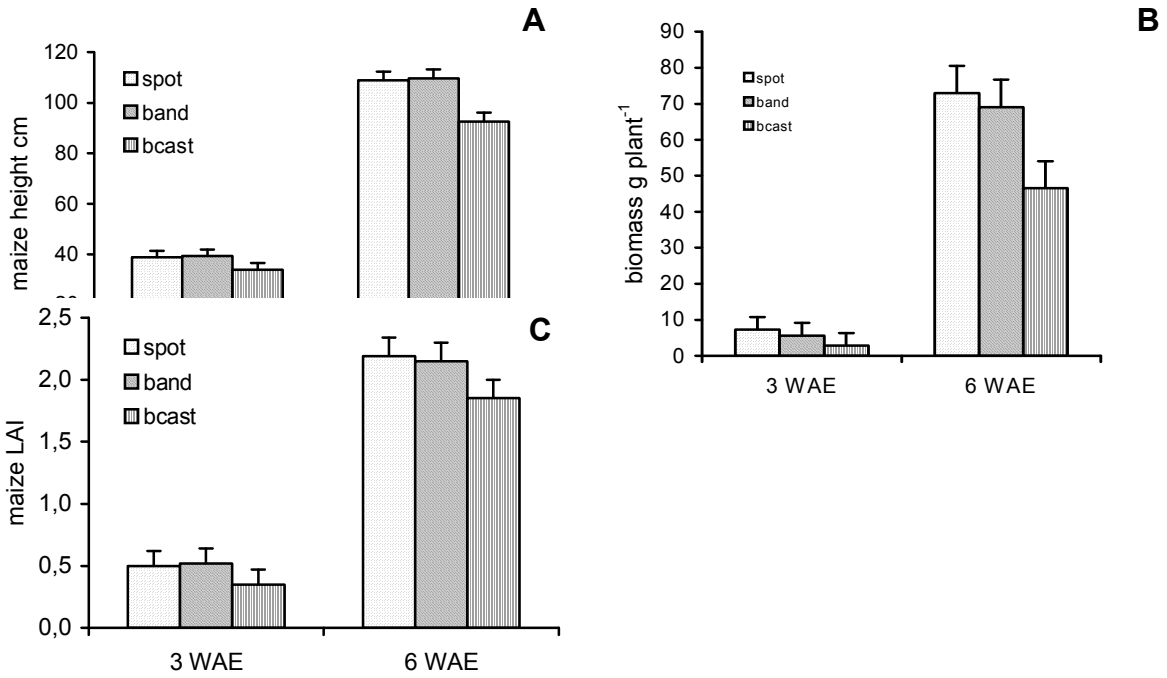


Figure 2: Effect of fertilizer placement on (A) maize plant height (in cm); (B) plant biomass (in g), and (C) leaf area index (LAI) at 3 and 6 WAE in Experiment 2. Error bars within each figure represent + standard error of the difference for the comparison of fertilizer placement means at 3 WAE (4df) and 6 WAE (10df) when maize plants were harvested

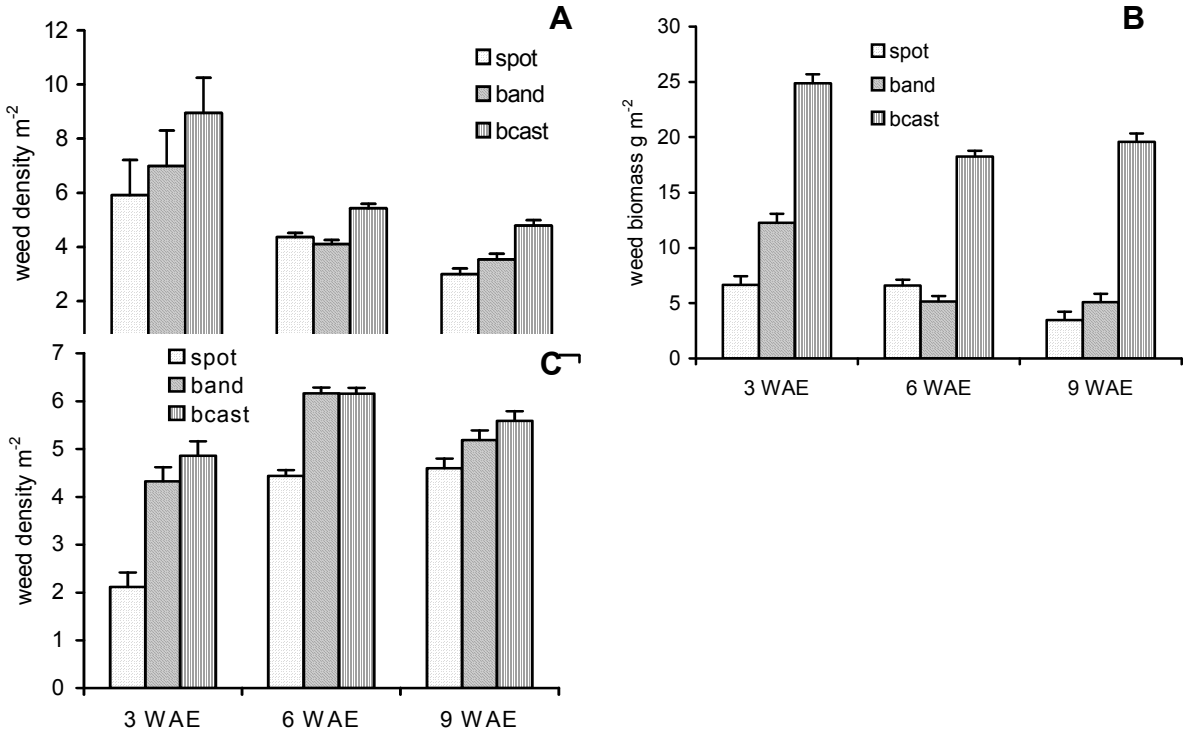


Figure 3: Effect of fertilizer placement on (A) weed density, (B) weed biomass in Experiment 2 and (C) weed density in Experiment 3. Error bars within each figure represent +standard error of the difference for the comparison of fertilizer placement means at 3 WAE (4df), 6 WAE (10df) and 9 WAE (16df) of weed measurement

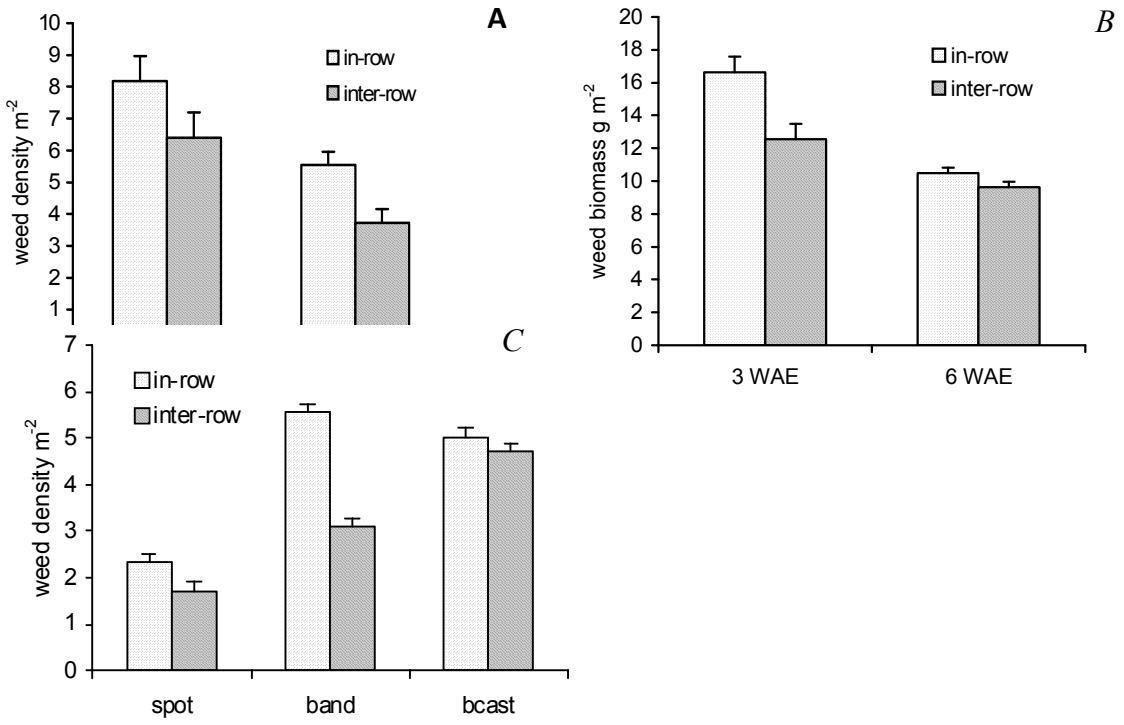


Figure 4: Weed density (A) and biomass (B) in the maize row and in the middle of the maize inter-rows in Experiment 2. (C) The effect of fertilizer placement on weed density in the row and in the middle of maize inter-rows at 6 WAE in Experiment 3. Error bars in each figure represent +standard error of the difference for the comparison of in-row and between- row means at 3 WAE (4df) and at 6WAE (10df) of measurement (A and B) and for each placement method (10df) (C)

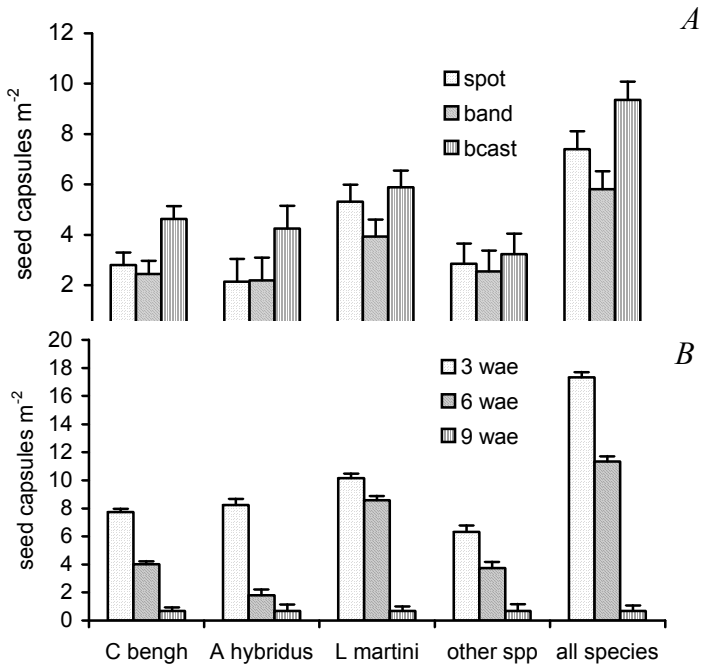


Figure 5: (A) Effect of fertilizer placement on weed seed capsule production in Experiment 2. (B) Effect of weeding regime on weed seed capsule production in Experiment 2. Error bars represent +standard error of the difference (16df) for the comparison of (A) fertilizer placement and (B) weed regime means within each species

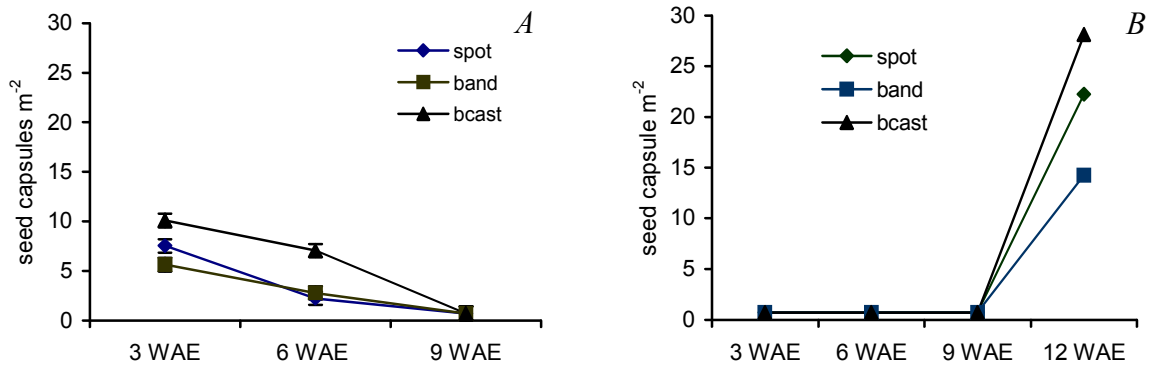


Figure 6: (A) Interaction between fertilizer placement method and weeding regime on C. benghalensis weed seed capsule production in Experiment 2. (B) Weed seed capsule production in Experiment 3. Error bars are ± interaction standard error of the difference {(A) 16df} and {(B) 22df) for the comparison of seed capsule number means within and between fertilizer placement methods

WATER TRANSPORT IN PLANTS: FROM MOLECULES TO WHOLE PLANT

M. Katsuhara
Institute of Plant Science and Resources, Okayama University, Kurashiki, Japan
E-mail: kmaki@rib.okayama-u.ac.jp

Abstract
Aquaporins are membrane proteins which provide a very efficient membrane transport system for water and low molecular weight compounds in living cells. We identified 23 barley aquaporin genes. Among tonoplast-type aqauporins (TIPs), TIP3;1 seems to be essential for seed maturation. Expressions of several plasma-membrane type aquaporins (PIPs) were down-regulated after strong salt (200 mM NaCl) or osmotic (360 mM mannitol) stresses, probably to prevent dehydration during salt/osmotic stresses. Inactivation of PIPs by dephosphorylation and internalization is also functional mechanism to prevent dehydration. Another regulation mechanism of PIP activity, heteromerization between PIP1 and PIP2 subgroups, was also investigated. Our research indicates that aquaporins are also involved in low-temperature tolerance. Molecular engineering/enhancement of aquaporins' functions may improve water relations, tolerance to some stresses, nutrition uptake, and finally increase of crop yield in future.

Key words: Aquaporin, barley, salt stress, water

1.0 Introduction

Water absorption/transport is a classical topic in biology and agricultural science; because all living cells require water. Drought (water-shortage) is one of the most serious limiting factors for crop yield. Although many scientists have worked in the field of plant water relations, almost no molecular mechanisms of water transport at cellular level were until aquaporins, membrane proteins which provide a very efficient membrane transport system for water, were identified in human erythrocyte (1992) and in plants (1993). Before the discovery of aquaporins, that water simply diffused "somehow'' across plants membrane and proteins were not involved in these processes (Schaffner 1998).

Plant aquaporins are classified as: PIP, TIP, NIP, SIP, and XIP (Table 1). In rice, 33 aquaporin genes are identified. In Arabidopsis, 35 aquaporins are known. Aquaporins were determined as a water channel at first, but now some aquaporins species are evidenced to transport low molecular weight compounds like H_2O_2, $Si(OH)_4$, $B(OH)_3$ NH_3, and CO_2 (Katsuhara *et al.,* 2008). However, profiling of substrate specificity in each aquaporin species is still on the way.

2.0 Materials and Methods

The seedlings of barley (*Hordeum vulgare*) were hydroponically grown as described (Katsuhara *et al.* 2002). Root samples were collected after NaCl/mannitol treatments and immediately frozen in liquid nitrogen, and then total RNA was extracted. Real-time RT-PCR was used for absolute quantification of RNAs (Mahdie *et al*. 2008). Water transport activity of each HvPIP was determined in *Xenopus* oocytes (Katsuhara *et al.* 2002). *In situ* localization of PIPs were investigated with the indirect immunofluorescence microscopy (Figure 1). Root hydraulic conductivity ($L p_r$, that is, water permeability) was calculated from a sap flow rate and driving pressure using the pressure chamber (Figure 2).

3.0 Results and Discussion

To date we identified 23 barley aquaporins. Among TIPs, TIP3;1 is more interesting because this aquaporin highly expressed in immature seed, especially in aleurone layers. TIP3;1 is thought to have essential role in seed maturation. Our collaborators have suggested that TIP3;1 highly expresses in maturing seeds of rice, too (Hayashi, personal communication).

From the aspect of water-related stress tolerance, we mainly focused on PIPs because, at the plasma-membrane, PIPs face stressful environment more directly than other aquaporins in endomembranes. PIPs were divided in to two subgroups, PIP1s and PIP2s. In roots, barley PIP1s (HvPIP1s) were detected in the vicinity of the xylem and the cortex. HvPIP2;2 was found in the epidermis, especially in cells developing root hair, and also detected in the stele. Among 10 HvPIPs, transcripts of some major HvPIPs (HvPIP1;2, HvPIP2;1, HvPIP2;2 and HvPIP2;3) were down-regulated after strong salt (200 mM NaCl) or osmotic (360 mM mannitol) stress (Figure 3). This may be an example of tolerance mechanism to prevent dehydration during strong salt/osmotic stresses (Figure 4). During mild stress (100 mM NaCl or isotonic 180 mM mannitol), no reduction of RNAs was observed, but other inactivation mechanisms are assumed to function to decrease PIP activity and $L p_r$. Aquaporins are known to be activated by phosphorylation. A protein kinase inhibitor (Staurosporin) reduces $L p_r$. Salt stress induced decrease of $L p_r$ but this reduction was partially inhibited by a protein-phosphates inhibitor (Okadaic acid), indicating that dephosphorylation of aquaporins is involved in the reduction of $L p_r$ during salt stress. Supplemental endocytosis inhibitor (Wartmannin) strongly inhibited the reduction of $L p_r$ by salt stress, suggesting that internalization of PIPs via endocytosis may occur during salt stress.

Another regulatory mechanism of PIP activity, heteromerization, was also investigated. Plant aquaporins are thought to form a tetramer to act as an active water channel protein (Törnroth-Horsefield *et al.*

2006). Heteromerization of PIP 1 and PIP2 aquaporins was proposed (Fetter *et al.* 2004). Co-expression of HvPIP1;2 with each HvPIP2 isoform significantly increased the water permeability in oocytes. Physiological function of heteromerization in the regulation of water transport activity awaits elucidation by further studies.

Aquaporins are also involved in low-temperature tolerance (Katsuhara *et al.* 2007). On the one hand, low-temperature tolerant figleaf-gourd plant can maintain root water permeability during chilling stress by increasing amounts of PIPs. On the other hand, sensitive cucumber plants cannot keep expression of aquaporins during chilling stress resulting in loss of water uptake. In addition to water transport and stress tolerance, recent studies have shown some aquaporins are involved in the transport of CO_2, ammonia, silica or boron.

4.0 Conclusions

Recent studies have revealed that aquaporins have essential roles in several physiological functions of plant cells. Molecular engineering to enhance of aquaporins' functions may play a useful role in improving water relations, tolerance to some stresses, nutrition uptake, and finally increase of crop yield in future.

Acknowledgements

Author expresses thanks for all collaborations of present and previous lab members and persons in other institutes/universities. Most part of this work was supported by a grant from the Program for the Promotion of Basic and Applied Research for Innovations in Bio-oriented Industries, Japan.

References

Fetter, K., Van Wilder, V., Moshelion, M. and Chaumont, F. (2004) Interactions between plasma membrane aquaporins modulate their water channel activity. *Plant Cell,* **16**, pp 215-228.

Katsuhara, M., Akiyama, Y., Koshio, K., Shibasaka, M. and Kasamo, K. (2002) Functional analysis of water channel in barley roots. *Plant Cell Physiology,* **43**, pp 885-893.

Katsuhara, M., Chung G. C., Sakurai, J., Murai, M., Izumi, Y. and Tsumuki, H. (2007). Low temperature and aquaporins, a molecular mechanism of water transport. *Cryobiology and Cryotechnology,* **53**, pp 21-32.

Katsuhara, M., Hanba, T. Y., Shiratake, K. and Maeshima, M. (2008). Expanding roles of plant aquaporins in plasma membranes and cell organelles. *Functional Plant Biology*, **35**, pp 1-14.

Mahdieh, M., Mostajeran, A., Horie, T. and Katsuhara, M. (2008). Drought stress alters water relations and expression of PIP-type aquaporin genes in *Nicotiana tabacum* plants. *Plant Cell Physiology,* **49**, pp 801-813.

Schaffner, A. R. (1998). Aquaporin function, structure, and expression: are there more surprises to surface in water relations? *Planta,* **204**, pp 131-139.

Törnroth-Horsefield, S., Wang, Y., Hedfalk, K., Johanson, U., Karlsson, M., Tajkhorshid, E., Neutze, R. and Kjellbom, P. (2006). Structural mechanism of plant aquaporin gating. *Nature,* **439**, pp 688–694.

Table 1: Description/localization of plant aquaporins and number of detected genes in barley

		Localization	No. of genes (Barley)
PIP	Plasma membrane Intrinsic Protein	Plasma membrane (PM)	10
TIP	Tonoplast Intrinsic Protein	Tonoplast (Vacuolar membrane)	8
NIP	Nodulin 26-like Intrinsic Protein	Bacteroid membrane, ER, PM	3
SIP	Small basic Intrinsic Protein	ER membrane	2
XIP	X Intrinsic Protein	Unknown (recently discovered)	-

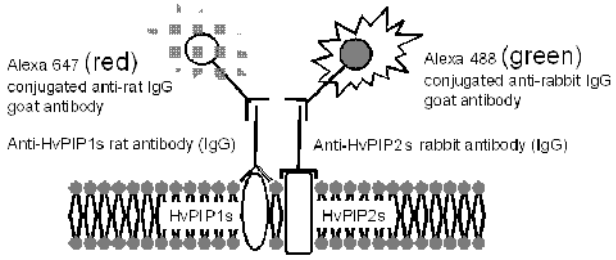


Figure 1: Indirect immunofluorescence

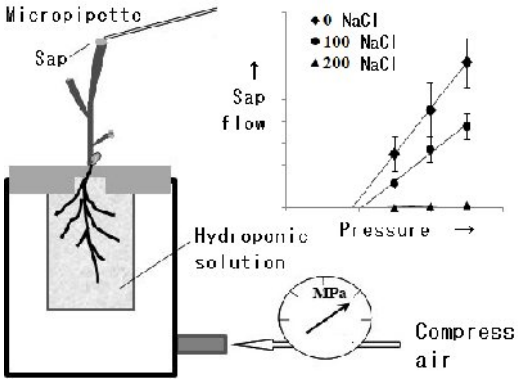


Figure 2: Pressure chamber
Sap flow = Lp_r x pressure – constant

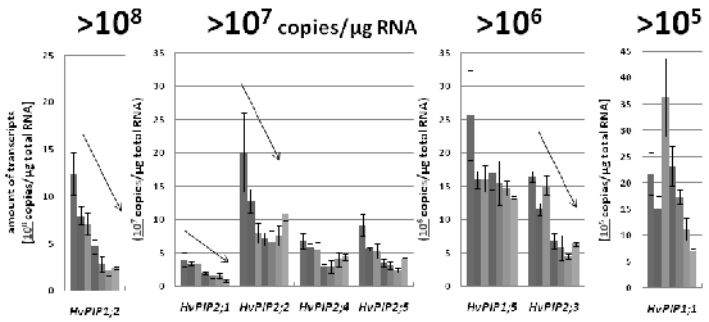


Figure 3: 200 mM NaCl reduced HvPIPs expression (left to right: 0, 2,4,6,8,12 and 24h NaCl)

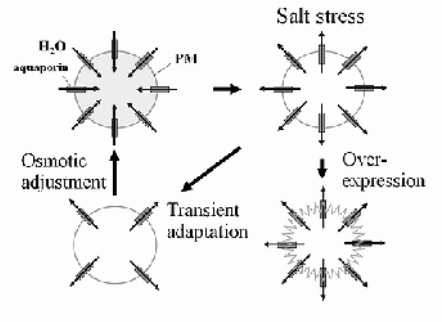


Figure 4: Dehydration model

CRYPTIC USEFULNESS OF *ORYZA LONGISTAMINATA*, AFRICAN WILD SPECIES OF RICE

M. Maekawa
Institute of Plant Science and Resources, Okayama University, Kurashiki, Okayama 710-0046, Japan
E-mail: mmaekawa@rib.okayama-u.ac.jp

Abstract
In the 21st century, several novel traits in crops should be possibly needed. Genetic resource is a jewel box for crop improvement. *Oryza longistaminata*, African wild species of rice is the most distantly related species from *O. sativa* within the Sativa group. Some characters of this species, long anther, large biomass and rhizomatous trait will be potentially useful in Next New Ideal Rice irrespective of high cross-incompatibility and hybrid sterility between two species. Long anther trait of *O. longistaminata* had been introduced into Shiokari, a variety in Hokkaido, Japan, through backcrossing. Segregants selected by long anther trait from *O. longistaminata* showed cool weather tolerance under cool summer condition, suggesting that long anther trait of *O. longistaminata* might be effective to cool weather injury at the booting stage. Large biomass trait was introgressed through selfing of selected lines derived from the cross between *O. longistaminata* and T-65. The selected lines showed stiff and long culm, large number of spikelets and relatively small number of panicles under non-fertilized conditions. Although global cultivars of rice are probably incompatible with *O. longistaminata,* some novel traits will be useful in the near future breeding program. Thus, these breeding materials derived from *O. longistaminata* are expected to be effective for new ideal rice.

Key word: *Oryza longistaminata*, *Oryza sativa*, anther length, cool weather tolerance, biomass

1.0 Introduction

In the 21st century, various new abiotic/biotic stresses potentially induced by increasing CO_2 concentration and global warming will attack various kinds of crops. It is urgently required to increase crop yield to feed increasing population in the world. High-input condition in modern agriculture have surely brought higher yields of crops by using short-statured varieties in "green revolution" in 1960s. However, these have induced various negative impact to environment; soil acidification, pollution of rivers, lakes and ground water and emission of global warming substances. In the 21st agriculture, it is important to gain high yield in sustainable conditions. For this, it is needed to maximize the crop-ability responsible for tolerances to various stresses. Wild relatives of crop is a jewel box for improvement of various traits. Wild relatives have not only visible usefulness but also cryptic usefulness. *Oryza longistaminata* Chev. et Roehr is a perennial species of rice in Africa, which is characterized by long anther, large stamen, rhizomatous trait and large biomass. Long anther and large stamen exerted long time of *O. longistaminata* are effective for outcrossing, suggesting that *O. longistaminata* is allogamous. Further, Khush *et al*., (1990) reported that *O. longistaminata* from Mali is tolerant to all races of bacterial blight in India. Although *O. longistaminata* carry the same AA genome as that of *O. sativa,* it is difficult to cross with *O. sativa* due to a crossing barrier (Chu and Oka, 1970) and hybrid sterility in F1 and F2 occurs. Further, it has been revealed that A genome of *O. longistaminata* is highly differentiated from that of *O. sativa*: *catalase* gene for antioxidant defense responds to environmental and physiological oxidative stress in *O. longistaminata* was found to have variation in number and sequence different from that of *O. sativa* (Iwamoto et al. 1998). Therefore, *O longistaminata* has not been utilized in breeding program so far. Single crossed seed between *O. longistaminata*, MwM from Kenya and a japonica varierty was obtained successfully. Using this F1 plant as a starting material, long anther trait of Mpunga wa majani (MwM) was introduced into japonica variety in Hokkaido, Japan, Shiokari by successive backcrossing. In segregating population, some tolerant plants to cool weather were found under natural cool conditions in Hokkaido, Japan. Further, large biomass trait of MwM was selected in selfed progeny derived from the F1 plant under non-fertilized conditions.

2.0 Materals and Methods

O. longistaminata, Mpunga wa Majani (MwM) collected at a valley 10km north from Mombasa, Kenya, was used in the study. MwM was crossed with japonica variety, Taichung 65 (T-65) and single crossed seed was obtained successfully. Any crossed seeds were not obtained when MwM was used as a pollen parent. As T-65 is a late-heading variety, an early heading plant selected in the F2 derived from the hybrid was crossed with Shiokari, a variety in Hokkaido, Japan. By successive backcrosses with Shiokari and selection with long anther and good fertility in greenhouse in winter, BC6F2 plants with Shiokari's background were produced. 10 BC6F2 populations were grown in 1992 and 1993. Especially, in 1993, many varieties of Hokkaido were attacked by cool summer and rice production in Hokkaido was severely decreased. As varietal differences to cool summer were observed, cool weather tolerances of the BC6F2 plants could be evaluated clearly under paddy field conditions in 1993.

Large biomass trait of MwM was selected in the selfed progeny derived from the cross between MwM and T-65 under non-fertilized paddy field of Institute of Plant Science and Resources, Okayama University. In order to maintain non-fertilized conditions, aero-parts of rice and wheat grown in winter were removed from the non-fertilized field and ground water was irrigated.

3.0 Results and Discussion

Frequency distributions of spikelet fertilities in 10 BC6F2 populations grown in 1992 and 1993 are shown in Fig.1. Although spikelet fertilities of Shiokari, a recurrent parent in 1992 and 1993 were low, segregations of spikelet fertilities in 1993 in 7 BC6F2 populations except #2, #4 and #5 populations were

extremely different from those in 1992. Especially, in #7 and 9 populations, segregation patterns of spikelet fertility in 1993 were different from those in 1992. Since summer in 1993 was cool, it was surmised that cool weather tolerant gene (s) were segregated in #7 and #9 populations. On the other hand, difference of segregation patterns of spikelet fertility between 1992 and 1993 was not observed in #5 population, indicating that cool tolerant gene (s) of F2 plants #5 population were fixed. Further, F2 plants in #7 population in 1993 were clearly segregated into fertile and low fertile groups, suggesting that a few cool weather tolerant genes were segregated in #7 population. Although the relation between anther lengths and spikelet fertilities of #7 population was not examined, BC7F1 plants had longer anthers than those of Shiokari. This suggested that long anther trait from MwM might be partly responsible for cool weather tolerance. It has been reported that long anther trait is correlated with cool weather tolerance though the physiological mechanism for cool weather tolerance at the booting stage remains unclear (Suzuki 1981; Satake 1986; Takeda 1990).

Although in early generation, selfed progeny from the cross between MwM and T-65 showed various degrees of spikelet sterilities and shattering trait derived from MwM, good-fertile and non-shattering progeny were selected in advanced generation. Under non-fertilized conditions, plants with large biomass were selected. As shown in Fig.2, plants selected carried long and thick culms and long panicles with large number of spikelets compared with Norin18 which was selected as a promising variety under non-fertilized conditions. Further, the selected plants showed large rhizosphere. On the other hand, heading of the selected plants was very late and number of tillers was small, indicating that these plants did not produce any non-productive tillers. These traits are found to be important for high yield under low fertilized conditions. Indeed, Khush (1999) pointed out that these characteristics are required in the 21^{st} century ideal rice. In order to transfer the large biomass trait into another varieties, it is needed to reveal QTL for large biomass using DNA marker and QTL analysis for large biomass trait is now ongoing.

4.0 Conclusions

Now, MwM//Shiokari backcrossed lines are maintained as recombinant inbred (RI) lines by successive selfing. Thus, various chromosomal fragments of MwM are possibly introduced in the RI lines. These materials bred are important as bridge materials to transfer useful traits of MwM into regional elite varieties. Next generation “green revolution” of rice is expected to be generated through introgression from wild relatives.

Referances

Chu, Y. E. and Oka, H. I. (1970). The genetic basis of crossing barriers between *Oryza perennis* subsp. *barthii* and its related taxa. *Evolution,* **24**, pp 135-144.

Iwamoto, M., Maekawa, M., Saito, A., Higo, H. and Higo, K. (1998). Evolutionary relationship of plant catalase genes inferred from exon-intron structures: isozyme divergence after the separation of monocots and dicots. *Theor. Appl. Genet*., **97**,pp 9-19

Khush, G. S. (1999). Green revolution: preparing for the 21st century. *Genome,* **42**, pp 646-655.

Khush, G. S., Bacalango, E. and Ogawa, T. (1990). A new gene for resistance to bacterial blight from *O. lingistaminata*. *Rice Genet. Newsl.,* **7**, pp 121-122.

Satake, T. (1986). Anther length as indicator to estimate chilling tolerance at the booting stage in rice plants. **In**: Napoempeth B, Sudhadrabandhu S. editors. New frontiers in breeding researches. Bangkok: Kasetsart University. pp 221-2218.

Suzuki, S. (1981). Cold tolerance in rice plants with special reference to the floral characters. In: Varietal differences in anther and stigma lengths and the effects of planting densities on these characters. *Japan Journal of Breeding*, **31**, pp 57-64 (in Japanese with English summary).

Takeda, K. (1990). Inheritance and character expression of a long kernel gene detected in a Japanese local variety “Fusayoshi”. *SABRAO Journal*, **22**, pp 79-90.

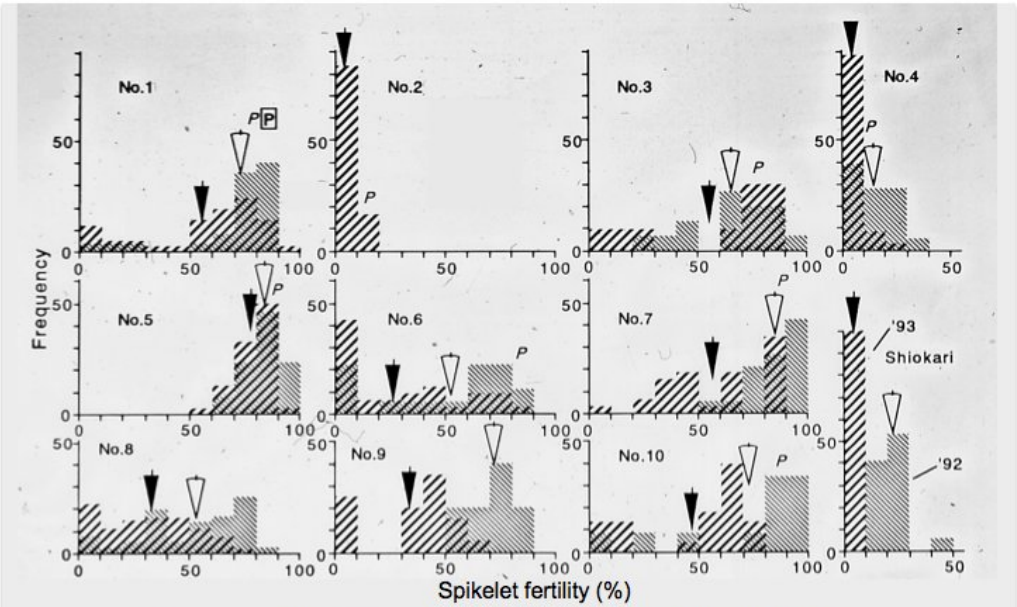


Fig.1. Frequency distributions of spikelet fertilities of MwM//Shiokari BC6F2 populations in 1992 and 1993.

P *: Spikelet fertility of BC5F1 plant in 1993. P : Spikelet fertility of BC6F1 plant in 1993.*

: Mean spikelet fertilities of BC6F2 plants in 1992 and 1993, respectively.

F

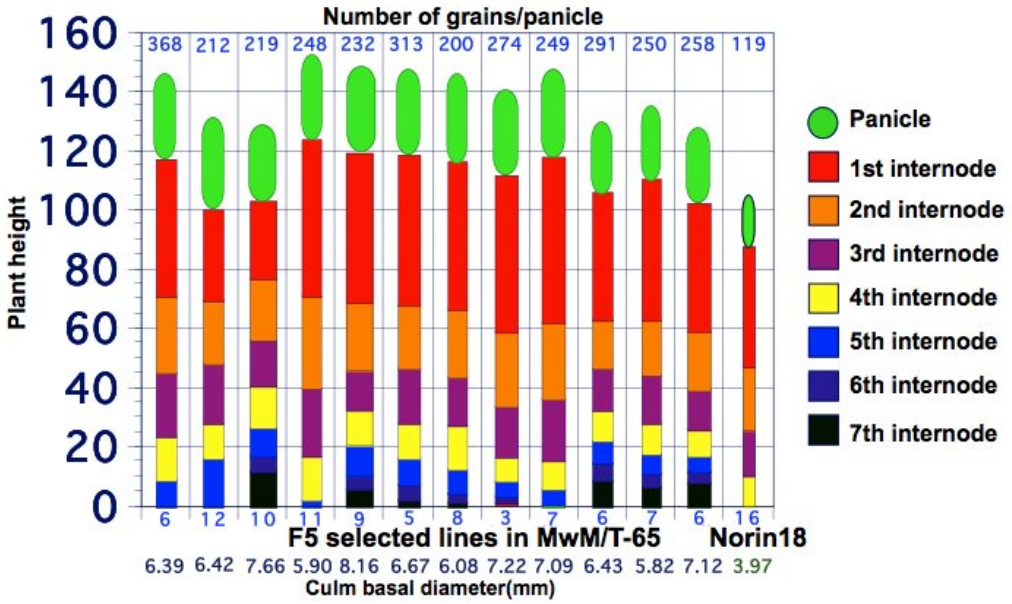


Figure 2: Illustrated agronomic traits of F5 lines selected from MwM/T-65 F2 in non-fertilized paddy field of IPSR

Norin 18; promising LIA variety selected in 300 varieties conserved at IPSR

VISUALIZATION OF STARCH GRAINS: A RAPID OBSERVATION METHOD TO ISOLATE MUTANTS WITH DEFECTS IN STARCH GRAIN MORPHOLOGY

R. Matsushima, M. Maekawa and W. Sakamoto
Institute of Plant Science and Resources, Okayama University, Kurashiki, Japan
E-mail: rmatsu@rib.okayama-u.ac.jp

Abstract
Starch is the most important carbohydrate for the human energy source contained in staple cereals and tubers and is also used for food additives such as thickeners and stabilizer. Starch consists of a large number of glucose units joined by glycosidic bonds and synthesized to form starch grains (SGs) inside plant cells. Despite the simple glucose polymer composition of starch, SGs exhibit various morphologies depending on plant species. The morphological variation of SGs supports the wide range of applications of starch, however the underlying molecular mechanisms have not yet been determined. We developed an effective method for preparing thin sections of seed endosperms without chemical fixation and conventional resin embedding that clearly visualize subcellular starch grains. We applied this method to genetic screening to isolate rice mutants in which starch grains were morphologically altered. In five mutants named *ssg* (*substandard starch grain*), increased numbers of small starch grains (*ssg1* to *ssg3*), enlarged starch grains (*ssg4*), and abnormal interior structures of starch grains (*ssg5*) were observed. The observation method is also applicable to other cereal grains, such as barley, wheat and maize. This method will also serve as a useful technique to study the molecular diversity of starch grain morphologies and to monitor the cereal grain qualities.

Key words: Endosperm, rice, starch, thin section, grain qualities

1.0 Introduction

Starch is a biologically and commercially important polymer of glucose and is synthesized to form starch grains (SGs) inside plastids (amyloplasts) of higher plants. Despite the simple composition of glucose polymers, SGs exhibit various morphologies depending on the plant species (Harz, 1880; Tateoka, 1962). Although SG morphological diversity was reported more than 100 years ago, the underlying molecular mechanisms that account for the differences in morphology have not yet been determined. In this study, we describe a rapid method to prepare thin sections of cereal endosperms without chemical fixation or resin embedding. Using this method, we performed a genetic screen and isolated five rice mutants defective in SG morphologies. Compared to conventional observation methods, the methods presented here are more effective for obtaining clear images of subcellular SGs and are highly suitable for the examination of a large number of samples.

2.0 Materials and Methods

Mutagenization was carried out by soaking *lax1* seeds in 1.5% (v/v) methanesulfonic acid ethyl ester (Sigma, Tokyo, Japan). The M2 line derived from a single M1 plant were grown and M2 seeds were collected from individual M1 plants after self-fertilization. Screening was carried out with at least five seeds from each M2 line. Endosperm thin sections from the M2 seeds were prepared by the rapid method. Starch staining was done by immersion in a drop of deionized water containing 40-times diluted Lugol solution (Iodine/Potassium iodine solution). The samples were subsequently examined under a microscope. To obtain thin sections of Technovit 7100 resin of endosperm, approximately 1-mm cubic blocks were cut out from the endosperm of dry seeds and fixed in FAA solution containing 5% (v/v) formalin, 5% (v/v) acetic acid and 50% (v/v) ethanol for at least 12 h at room temperature. Samples were subsequently dehydrated through a graded ethanol series (30% [v/v], 50%, 70%, 90% and 100%) and then embedded in Technovit 7100 resin (Kulzer and Company, Wehrheim, Germany). The embedded samples were cut with ultramicrotome and glass knives and dried on coverslips. Thin sections (approximately 1 □m thickness) were stained with the diluted Lugol solution and subsequently examined under a microscope.

3.0 Results and Discussion

We developed a rapid method to prepare thin sections of mature endosperms (Figure 1). A mature rice seed was fitted into a truncated 200-□L pipette tip (Figure 1A). For rice and barley, truncated 200-□L tips were appropriate. For maize, a truncated 1-mL pipette tip was suitable. The seed-embedded tip was fixed on a block trimmer that was originally developed for resin block trimming for ultramicrotomy (Figure 1B). The fixed seeds on the block trimmer were manipulated under a stereo microscope. The block trimmer was held by third and fourth fingers of non-dominant hand (Figure 1C), while index finger and thumb of dominant hand held a razor blade attached to the seed. During trimming, the blade was kept horizontal–to the seed. The blade was also supported by index finger of non-dominant hand to adjust trimming pressure. Trimming generated a smooth surface on the top of the seed, which was exposed approximately 1 mm out of the pipette tip. Thin sectioning was performed as trimming with the same hand positions, but we kept the angle of the blade approximately 30°. The seeds were easily trimmed using a razor blade (Figure 1D), and thin sections were shaved off the endosperms (Figure 1E). Forceps were used to take and place thin sections onto glass slides for staining.

To test the effectiveness of this method, we tried to prepare thin sections of three cereal species: rice, maize, and barley (Figure 2A). Thin sections prepared using the rapid method were stained with iodine and examined under a microscope. The morphologies of SGs were clearly observed. Rice SGs showed compound grains in which smaller granules were assembled. Occasionally, simple grains were also observed. Maize had simple grains that were round and uniform in size. In barley, we observed small

(approximately 5 □m in diameter) and larger (approximately 20 □m in diameter) simple grains coexisting in the same cell.

To isolate morphologically distinct SG mutants, we screened ethylmethane sulfonate (EMS)-treated M2 seeds using the rapid method. We examined at least five seeds from each M2 line. Of the 1152 M2 lines, five independent mutants with abnormal SG morphologies were isolated. All mutant grains showed chalky endosperms. To obtain fine images of SGs, we chemically fixed endosperms and embedded them in Technovit resin. Technovit sections (approximately 1 □m thick) were prepared and stained with iodine (Figure 2B). Normal SGs were uniform in size and approximately 10-20 □m in diameter. In *ssg1, ssg2,* and *ssg3* mutants, many smaller, simple grains (less than 10 □m in diameter) were observed, in addition to the normal compound grains. In *ssg4* mutants*,* larger SGs (greater than 30 □m in diameter) were detected. SGs without internal compound structures were observed in *ssg5* mutants. All of these phenotypes were inherited in subsequent generations.

When *ssg1* was crossed with Kasalath, 20 out of 109 F2 seeds showed the coexistence of simple and compound grains in their endosperms, indicating that *ssg1* segregated as a single recessive allele (χ^2 = 2.6, P = 0.11). *ssg1* was mapped to the middle of chromosome 2 where the *Amylopectin Branching enzyme IIb* gene (*BEIIb*, Os02g0528200) is located (Harrington et al., 1997). We determined the genomic sequence of the *BEIIb* gene from the 5' UTR through to the 3' UTR in the *ssg1*, *ssg2* and *ssg3* mutants, and found several base changes. In *ssg1*, two base changes were identified in introns. One was located in the 12th intron splicing acceptor site. The guanine residue (+5789) essential for correct mRNA splicing was replaced by adenine. The *ssg2* mutant also had two base changes. One was located in the 18th exon, which caused an amino acid substitution from proline to leucine. In *ssg3,* a base change was found in the 17th exon, resulting in a glycine to arginine substitution.

4.0 Discussion and Conclusions

Many *Poaceae* species have been examined, mostly in extracted conditions, for SG morphologies. We are now reevaluating SG morphologies of the *Poaceae* species using the rapid and resin-embedding methods to verify previous observations and discover novel types of SGs with unique morphologies. Molecular analysis focusing on the mechanisms that determine SG morphology and descriptive analysis of cross-species SG diversity will lead to a more complete understanding of the molecular diversity of SG morphologies. This method will also serve as a useful technique to understand the molecular diversity of starch grain morphologies and to check the cereal grain qualities.

References

Harrington, S. E., Bligh, H. F. J., Park, W. D., Jones, C. A. and McCouch, S. R. (1997). Linkage mapping of starch branching enzyme II in rice (*Oryza sativa* L.) and prediction of location of orthologous genes in other grasses. *Theor Appl Genet,* **94**, pp 564-568.

Harz, C. O. (1880). Beiträge zur systematik der Gramineen. *Linnaea,* **43**, pp 1-30.

Tateoka, T. (1962). Starch grains of endosperm in grass systematics. *Bot Mag Tokyo,* **75**, pp 377-383.

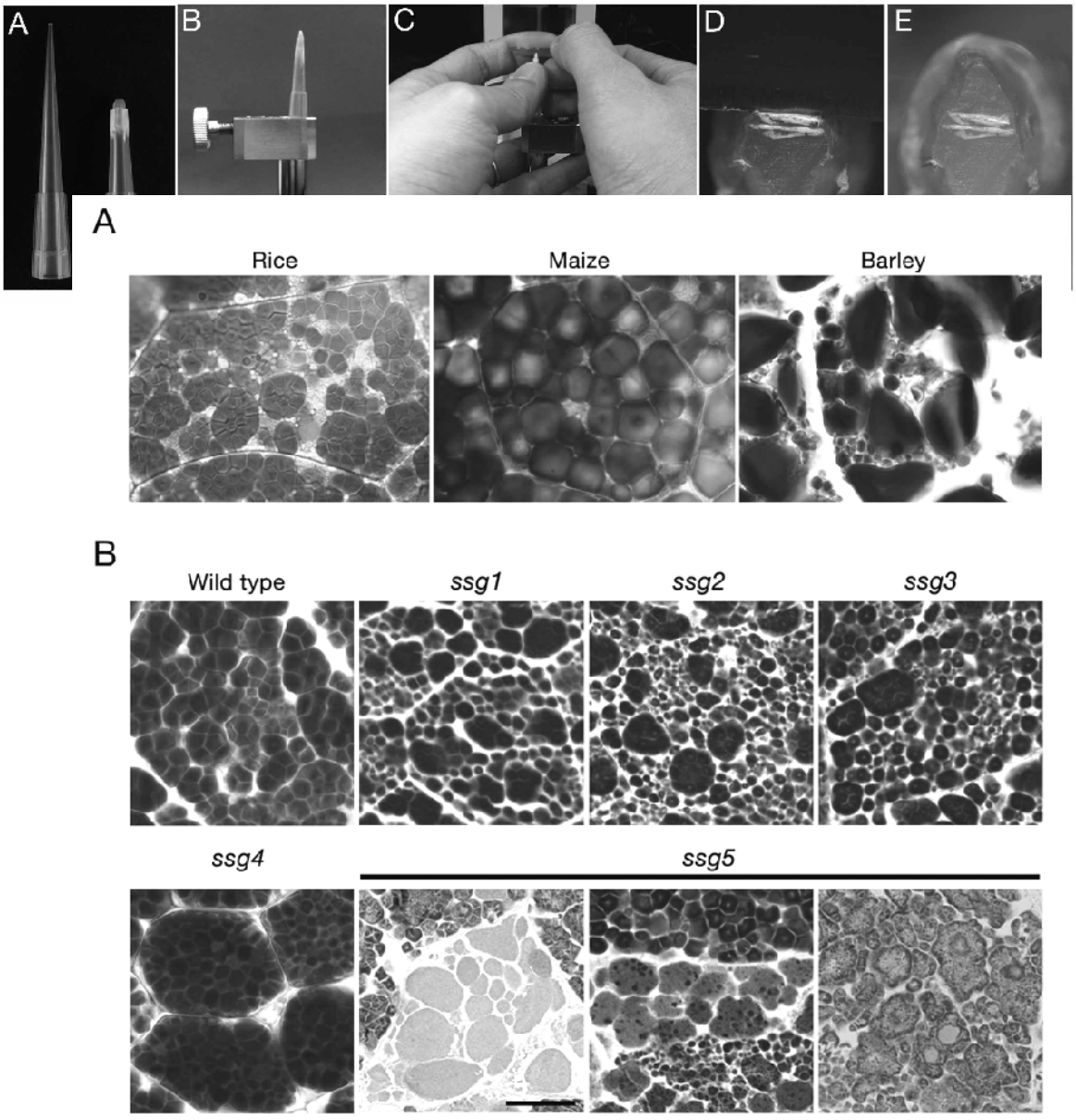


Figure 2: Starch grain morphologies of three cereal species and the isolated mutants. Bars = 20 m.

NOVEL MECHANISM OF ALUMINUM TOXICITY RELATED TO SUGAR METABOLISM

Y. Yamamoto and T. Sasaki
Institute of Plant Science and Resources, Okayama University, Okayama, Japan
E-mail: yoko@rib.okayama-u.ac.jp

Abstract
Aluminum ion is a major factor to limit crop productivity in acidic soils. Aluminum ion accumulates on root apices, which immediately leads to the inhibition of cell elongation (namely, the inhibition of root elongation). In addition, the enhancement of reactive oxygen species (ROS) production is commonly observed in roots under aluminum stress. These symptoms are also observed in actively growing cells in culture. The elucidation of the mechanisms of aluminum toxicity is necessary to find out effective strategies to overcome aluminum stress. For this purpose, we investigated the responses to aluminum in cultured cell system as well as root system of tobacco, focusing on sugar metabolism. We found that aluminum ion immediately inhibits sugar uptake, which seems to be a mechanism whereby aluminum ion inhibits water uptake (namely, the inhibition of cell elongation). The pathway from the inhibition of sugar uptake till ROS production in the cells under aluminum stress should be elucidated in the future.

Key words: Aluminum toxicity, cell elongation, ROS, sugar uptake, water potential

1.0 Introduction

Free aluminum ions are the main factor responsible for inhibiting root growth in acidic soils (Matsumoto, 2000; Kochian *et al*., 2004). The primary site of aluminum accumulation and toxicity is the growing cells at root tip, where aluminum inhibits elongation after a short-term exposure, and causes necrosis after longer exposure. Primary targets of aluminum seem to be within the cell wall and at the plasma membrane. However, the targets and mechanisms whereby aluminum inhibits elongation have not been fully elucidated. Elongation depends on three events, namely, synthesis of cell wall constituents, loosening of the cell wall, and water uptake. Although aluminum might inhibit any or all of them, we focused on the effect of aluminum on water relations in this study.

A system for studying aluminum responses at cellular level has been developed using a tobacco cell line SL. The cell line system is useful for the study of mechanisms of cell elongation and division, since they are relatively homogeneous and their growth conditions are easily controlled, and each cell is in contact with aluminum ions in medium. In this system, we observed several toxicity symptoms similar to those of roots, namely, cell elongation inhibition, callose production, ROS production, respiration inhibition, ATP depletion (Yamamoto et al., 2002, 2003). The details of aluminum toxicity mechanisms can be investigated in this simple cell systems.

Here, we investigate the mechanism of elongation inhibition by aluminum, focusing on water relations in both cultured tobacco cells and tobacco seedlings. We report that along with blocked elongation, aluminium-treated cells fail to accumulate soluble sugars and have a low cellular osmolality. Aluminium reduces sugar uptake substantially within a few hours. We suggest that the inhibition of sugar uptake by aluminum is a primary event, responsible for lowered osmolality and hence lowered water uptake and the inhibition of elongation.

2.0 Materials and Methods

2.1 Tobacco Cells and Seedlings, Media, Aluminum Treatment

A wild-type line (SL) was derived from Nicotiana tabacum L. cv. Samsun (Nakamura *et al*., 1988). Tobacco cells at the logarithmic phase of growth were suspended in medium containing 3 mM CaCl2, 88 mM sucrose, and 20 mM MES, pH 5.0 adjusted with bis-tris propane (treatment medium) and various concentrations of AlCl3 at a cell density of 10 mg fresh weight per mL, and cultured for up to 18 h on a rotary shaker operated at 100 rpm at 25˚C in the dark (Abdel-Basset et al. 2010). Aluminum-treated cells tended to adhere to glassware; therefore, glassware was coated with Sigmacoat (Sigma-Aldrich, St. Louis, MO. USA). Seeds of tobacco (cv. Samsun) were surface sterilized, and then placed on the nylon net set in the mount which was floated on Ruakura growth medium at pH 6.0 (Snowden and Gardner, 1993) on a cycle of 16-h days (~200 µmol m^{-2} s^{-1} light) and 8-h nights. At about 7-day after germination, root parts were treated with aluminum in Ruakura medium containing 10 mM Mes at pH 5.0 for up to 3 days. If it was necessary, sucrose was added in the treatment medium, and the seedlings were treated in the dark, unless otherwise indicated. For fresh weight measurement, cells in 10-mL aliquots were harvested on filter paper by vacuum filtration and fresh weight was determined (Abdel-Basset *et al*., 2010).

Aluminum sensitivity of cell lines was determined as post-treatment growth capacity in the absence of aluminum (Abdel-Basset *et al*., 2010). In brief, cells for assay were harvested (in 10-mL aliquots), washed, suspended in 30-mL of nutrient medium, and cultured for 7 days. The increase in fresh weight over that week was called post-treatment growth and expressed as a percent of the control.

2.2 Assessment of Osmolality of Medium and Cell Sap

Osmolality of the solutions and cell sap were determined with a freezing point osmometer; Model 210, Fiske Associates, Norwood, MA, USA (Abdel-Basset *et al*., 2010).

2.3 Measurements of Soluble Sugar Contents, Sugar Composition, and Sucrose Uptake

Soluble sugars in cultured cells and root apices (5 mm) were extracted with 80% ethanol at least two times at room temperature, and the measurement of soluble sugar contents was performed by the anthrone reaction, and was expressed as glucose equivalents (Abdel-Basset *et al.,* 2010). This assay quantifies principally free hexose and the hexose moiety derived from oligosaccharides during heat treatment with anthrone-sulfuric acid reagent.

To determine the rate of sucrose uptake in tobacco cells, [U-^{14}C] sucrose was added to the culture and incubated. Then, aliquots of the culture were harvested on a glass membrane filter by vacuum filtration and washed with the treatment medium. The cells on the filter were dried, and the radioactivity on the filter was determined with a scintillation counter (Abdel-Basset, *et al*., 2010).

3.0 Results and Discussion

3.1 Tobacco Cell System

Over an 18-h treatment period, aluminium inhibited the increase in fresh weight (mainly due to water uptake) almost completely and decreased cellular osmolality and internal soluble sugar content substantially (Abdel-Basset et al., 2010). Soluble sugar comprised mainly glucose (32% of total), fructose (36%) and sucrose (16%) in control, and glucose (34%), fructose (38%) and sucrose (8%) in aluminium-treated cultures. In aluminium-treated cultures, fresh weight, soluble sugar content, and osmolality decreased over the first 6 h and remained constant afterward, contrasting to their 6 continued increases in the untreated cultures. Aluminium did not affect the concentrations of major inorganic ions. The rate of sucrose uptake, measured by radio-tracer, was reduced by approximately 60% within 3 h of treatment (Abdel-Basset et al., 2010). Aluminium also inhibited glucose uptake. On the other hand, aluminium responses such as the evolution of ROS and the loss of growth capability were observed after 6-h exposure to aluminium. Thus the events related to aluminum-induced cell elongation inhibition such as the repression of water uptake and the repression of sucrose uptake occur simultaneously as early events, while the events related to aluminuml-induced cell death such as ROS production and the loss of growth capability, as well as respiration inhibition, ATP depletion and callose production (Yamamoto *et al*., 2002; Yamamoto *et al*., 2003), occur as late events. Further separating the effects of aluminium on elongation and cell survival, sucrose starvation for 18 h inhibited elongation and caused similar changes in cellular osmolality but stimulated the production of neither ROS nor callose and did not cause cell death (Abdel-Basset *et al*., 2010).

Taken together, we propose that the inhibition of sucrose uptake in tobacco cells is a mechanism whereby aluminium inhibits elongation, but does not account for the induction of cell death.

3.2 Tobacco Root System

Root elongation of tobacco seedlings depends on light. In the presence of light, root elongation occurred continuously at least for 4 days (~2.3 mm d^{-1}) (Figure 1A), with an increase in free sugar content at root apex (Figure 1B). However, in the absence of light, root elongation was completely inhibited (Figure 1A) and the free sugar content at root apex was decreased (Figure 1B). These results strongly suggest that root elongation depends on the supply of photoassimilates (sucrose) from shoots. To support this, the exogenous supply of sucrose (or glucose) in medium supported root elongation even in 7 the dark condition (Figure 2). Under the dark condition with exogenous sucrose (50 mM),

however, the addition of aluminum in medium immediately prevented the increase in free sugar content at root apex and root elongation. Net increases in free sugar content in root apex (μg $apex^{-1}$) were 60 (at 2 h), 960 (6 h) and 1279 (24 h) in the absence of aluminum, while 0 (2 h), 68 (6 h) and 711 (24 h) in the presence of 200 μMAl. After 24 h treatment with 200 μM Al, root elongation level was 40% of control. These results strongly suggest that the inhibition of sucrose uptake by aluminum simultaneously inhibits cell elongation.

4.0 Conclusion

In plant cells, the increase in osmolality in vacuole is fundamentally necessary for water uptake, and the increase in osmolality will be performed by increases in inorganic ion concentrations and/or free sugars. Based on the responses to aluminium commonly observed in cell culture and root systems of tobacco, we propose that the accumulation of aluminium on actively growing cells at root apex or in culture inhibits the accumulation of free sugar in vacuole via the uptake inhibition of sucrose and/or glucose, which could be a mechanism whereby aluminium inhibits cell elongation, but does not directly account for the induction of cell death (Figure 3).

Acknowledgement

We thank Ms Rikishi Sanae, Masako Fujikawa, Kazue Komatsu for their skilled assistance in experiments. This study was supported by a Grant-in-Aid for General Scientific Research from the Ministry of Education, Culture, Sports, Science and Technology of Japan (nos. 18208008, 21580078), and Ohara Foundation for Agricultural Sciences.

References

Abdel-Basset, R., Ozuka, S., Demiral, T., Furuichi, T., Sawatani, I., Baskin, T. I., Matsumoto ,H., Yamamoto, Y. (2010). Aluminium reduces sugar uptake in tobacco cell cultures: A potential cause of inhibited elongation but not of toxicity. *Journal of Experimental Botany*, **61**, pp 1597-1610.

Kochian, L. V., Hoekenga, O. A., Pineros, M. A. (2004). How do crop plants tolerate acid soils? Mechanisms of aluminum tolerance and phosphorous efficiency. *Annual Review of Plant Biology*, **55**, pp 459-493.

Matsumoto, H. (2000). Cell biology of aluminum toxicity and tolerance in higher plants. *International Review of Cytology*, **200**, pp 1-46.

Nakamura, C., Telgen, H. V., Mennes, A. M., Ono, H., Libbenga, K. R. (1988). Correlation between auxin resistance and the lack of membrane-bound auxin binding protein and a root-specific peroxidase in Nicotianatabacum. *Plant Physiology*, **88**, pp 845-849.

Snowden, K. C. and Gardner, R. C. (1993). Five genes induced by aluminum in wheat (Triticum aextivum L.) roots. *Plant Physiology*, **103**, pp 855-861.

Yamamoto, Y., Kobayashi, Y., Devi, S. R., Rikiishi, S., Matsumoto, H. (2002). Aluminum toxicity is associated with mitochondrial dysfunction and the production of reactive oxygen species in plant cells. *Plant Physiology,* **128**, pp 63-72.

Yamamoto, Y., Kobayashi, Y., Devi, ,S. R., Rikiishi, S., Matsumoto, H. (2003). Oxidative stress triggered by aluminum in plant roots. *Plant and Soil*, **255**, pp 239-243.

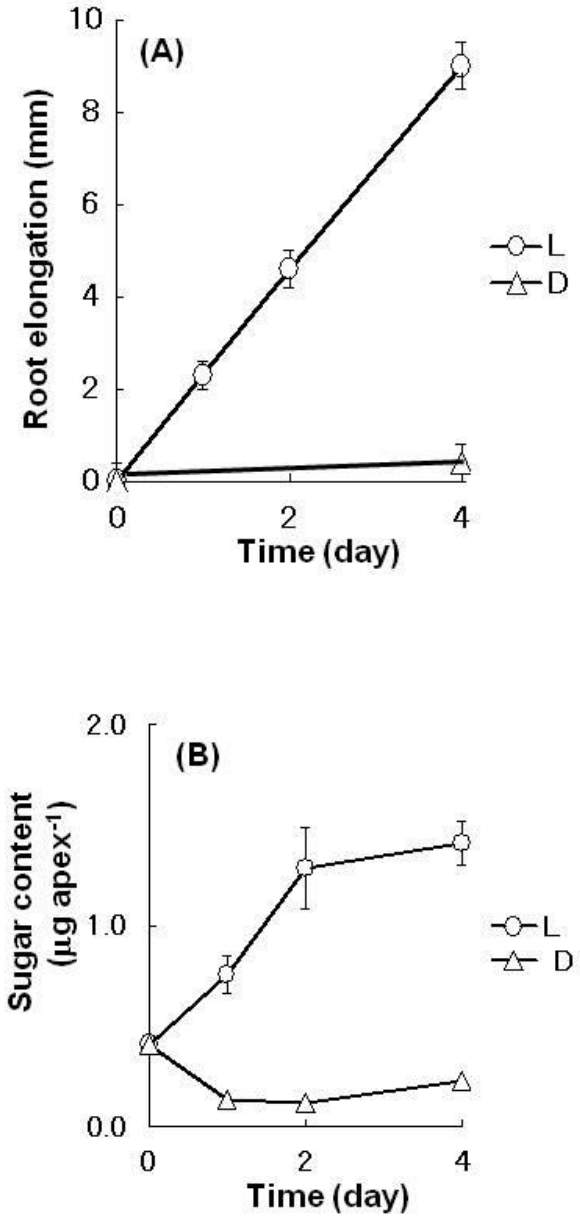


Figure 1: Root elongation of tobacco seedlings depends on the light

Tobacco seedlings were hydroponically cultured in growth medium in the light (O) or dark (△) condition for up to 4 days. At times, root length (A) and free sugar content at root apices (B) were determined.

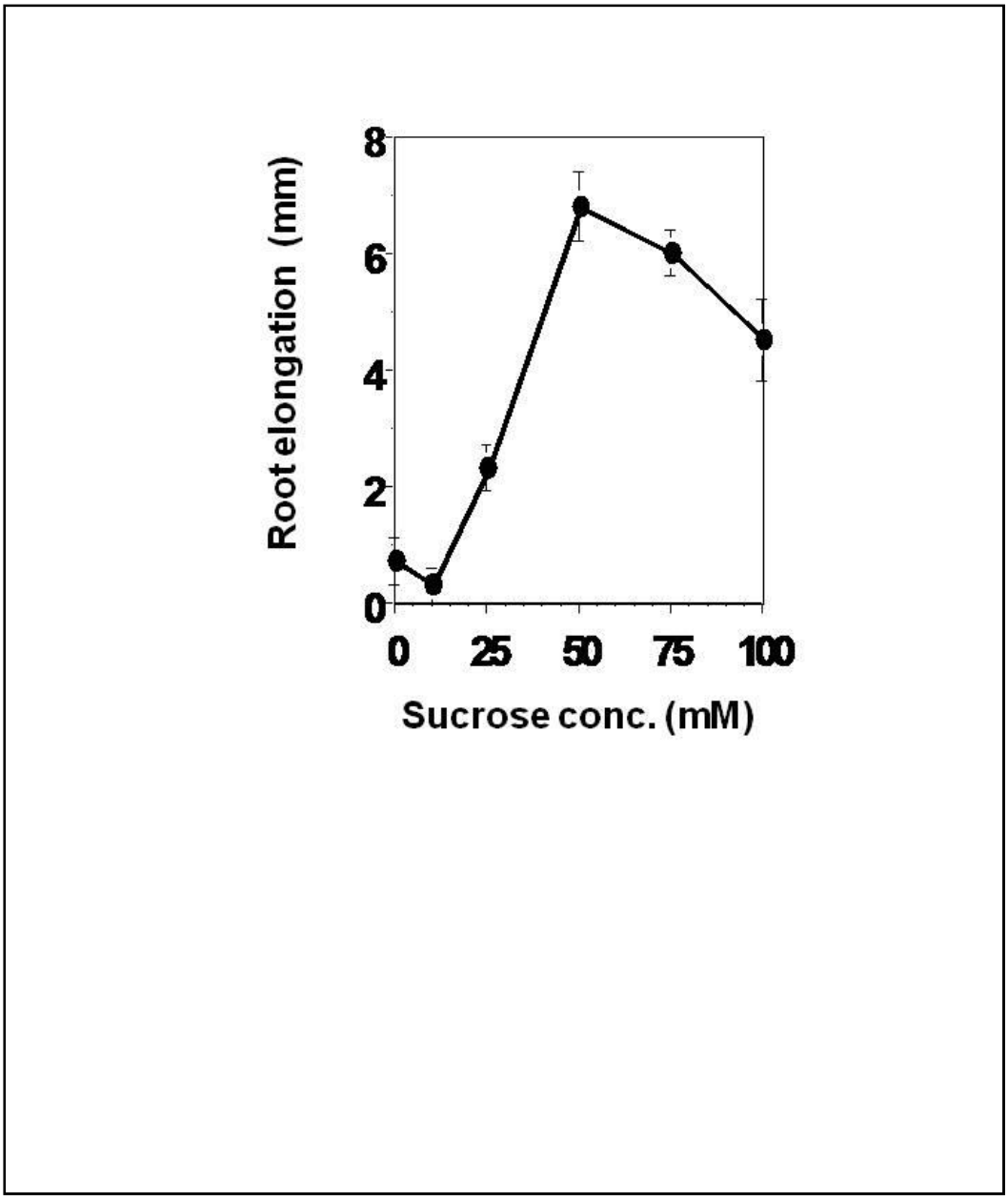


Figure 2: Exogenous supply of sucrose supports root elongation of tobacco seedlings in the dark

Tobacco seedlings were hydroponically cultured in growth medium containing various concentrations of sucrose, in the dark for up to 3 days. Root length was measured at a start and after 3 days, and root elongation during the culture was determined.

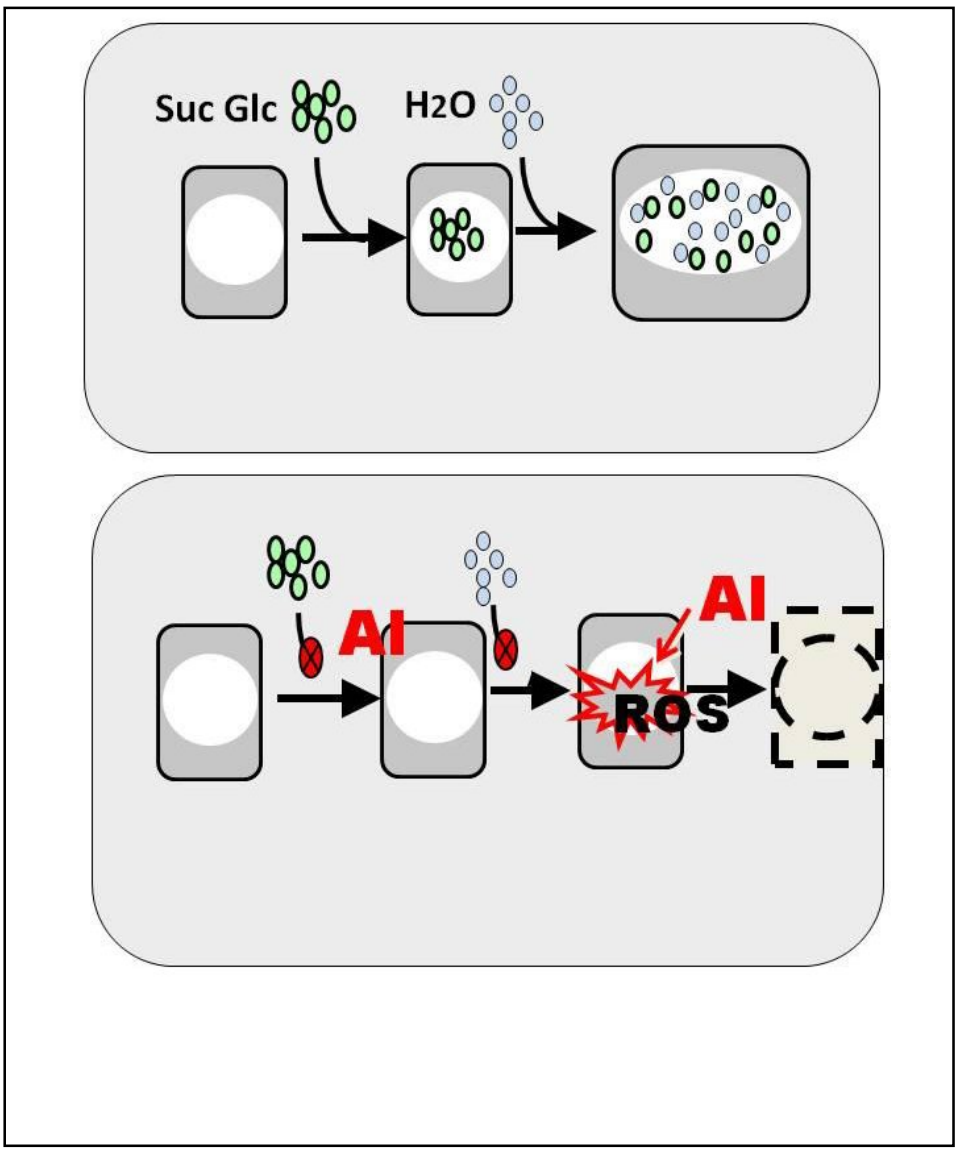


Figure 3: Model for a mechanism of aluminum-induced cell elongation inhibition in tobacco cells

Without aluminum (Top), the uptake of sugars increases osmolality, which could be a motive force of water uptake into vacuole, hence cell elongation. With aluminum (bottom), the uptake of sugar is inhibited, which prevents water uptake, hence cell elongation. The aluminum-induced root elongation inhibition seems to be explained by this mechanism. Other events caused by aluminum, such as callose production, respiration inhibition, ROS production, ATP depletion, start in relatively late phase and seem to be related to cell death.

POSTERS

THE ROLE OF AGROFORESTRY IN THE SEMI-ARID KAITI WATERSHED, MAKUAENI

A. W. Muriuki[1], M. Gathenya[2] and W. Kaluli[3]
[1]Kenya Agricultural Research Institute, National Horticultural Research Centre, Thika, Kenya
[2,3]Department of Biomechanical and Environmental Engineering, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: muriukianne@gmail.com

Abstract
In assessed water supply with a view to improving its management for domestic use and agricultural production, one objective was to investigate how farmers had integrated agroforestry into farming in Kaiti Watershed. The survey found agroforestry to be widespread, but mainly concentrated in the wetter Kaiti and Kilungu Divisions. Most trees were grown along hedges or interspersed between crops. Fruit trees were preferred over other tree types. Avocado (68%) and mango (68%) were more widely grown than citrus (16%), papaya (13%), or indigenous fruit trees like loquats, guava, custard apple and croton (<5% each). The most popular non-fruit trees were eucalyptus (27%), *Grevillea* spp (24%) and neem (21%) but cypress, red pod terminalia, cedar, acacia, wattle and pine were also present. Residents preferred multipurpose trees and used them for food (84%), fuel (83%), construction (38%), bee-keeping (5%), fencing (29%), medicine (3%) and soil fertility improvement (19%). Most residents grew trees on-farm for subsistence, because earnings from this enterprise were low (<KSh 5000 yr^{-1}) and relied mostly on themselves for information. Future efforts should focus on growing indigenous fruit trees to enhance food security, mitigate the impacts of climate change and generate income.

Key words: Agroforestry, multipurpose trees, income generation, information sources

1.0 Introduction

Makueni district in which Kaiti watershed is located is situated in South-eastern Kenya. The district covers 744,000 hectares and 64% is semiarid (Figure 1). Rainfall averages about 500 mm annually usually falling over a few days so water losses from runoff are high. The predominant landuse is mixed farming (Jaetzold and Schmidt, 1983), incomes from agriculture are low. Contributing factors include low disposable incomes, intense land pressure due to a rapidly rising population, diminishing land holdings, erratic rainfall patterns, constant droughts, declining soil fertility, massive soil erosion, elevated termite activity and distant markets (Muriuki, 2004; Gichuki, 2000a,b; Gichuki *et al*., 2000; Mbuvi, 2000). Consequently, food insecurity is a serious problem, especially after droughts, so food donations are common (Kaluli *et al*., 2005; Muriuki, 2004, Gichuki *et al*., 2000; Mbogoh, 2000). In 2005 for example, Makueni district produced only 9% of the estimated cereal demand of 127,720 MT (Anonymous) necessitating food donations. Most farmers aim at meeting at least 67% of their food demand in a good year from their farm produce, buying the rest off-farm. However in drought years, they have to buy greater quantities than the one-third usually bought off-farm.

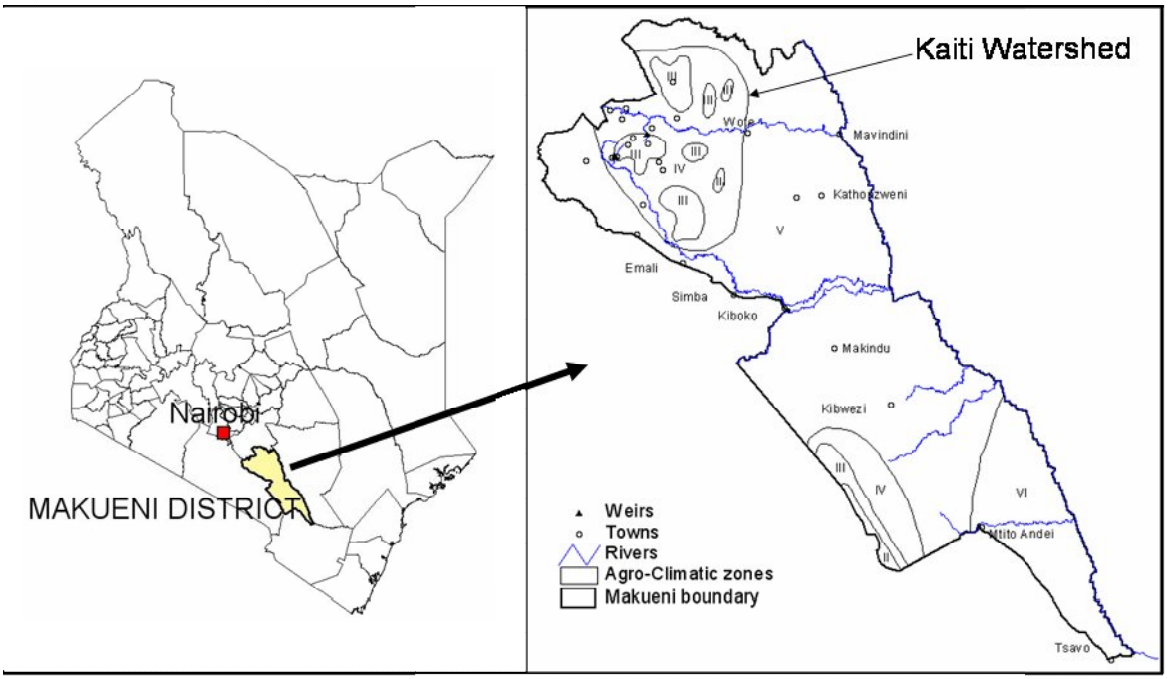


Figure 1: Map showing location agro-ecological zones of Makueni District

Kaiti watershed (Figure 2) is a sub-catchment of the Athi River basin. Spanning over five divisions, namely, Kilungu, Kee, Kalama, Kaiti and Wote, it covers approximately 660 km^2. Most of the watershed is semi-arid, but Kilungu and Kaiti are more humid because of their high elevation. Soils are predominantly sandy to loamy sand in texture with low organic matter contents which makes them very susceptible to erosion and limits their capacity to retain water and plant nutrients. Agricultural production is low and primarily limited by low inherent soil fertility, low erratic rainfall, soil erosion especially on steep slopes and siltation of manmade reservoirs downstream river Kaiti.

As in the rest of Makueni district, food shortages are common in Kaiti watershed, especially following seasons with drought. Central to this problem however is perennial water shortage. Residents of Kaiti watershed frequently harvest water. The water-harvesting system comprises a catchment area which

acts as both source and storage of the water harvested. Catchments can be natural slopes, rocks, roofs, and roads. Harvested water can be used for domestic purposes, to water livestock and for production of crops, pasture and trees. In 2004, a project was initiated in Kaiti watershed to assess water supply with a view to improving its management for domestic use and agricultural production. One objective was to investigate how farmers had integrated agroforestry into farming.

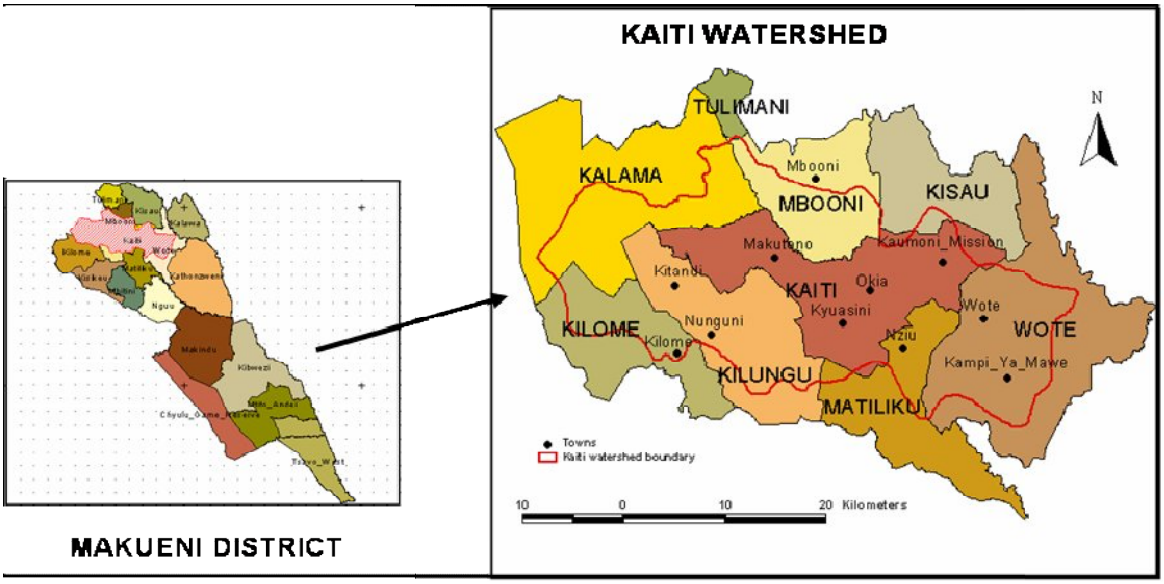


Figure 2: Location of Kaiti Watershed in Makueni District

2.0 Materials and Methods

Kaiti watershed falls between 1^{o} 38' 24" S and 1^{o} 51' 35" S; and 37 ^{o} 14' 10" E, and 37 ^{o} 41' 45" E. A structured questionnaire was administered to respondents sampled systematically along three transects, each running in a north-south direction, across Kaiti river (Figure 3). Before administering the questionnaire, field assistants were trained in an 'in-class' session followed by a 'hands on' practical and finally, an 'in-class' review session. Data was collected on various topics including the farm labor structure, livestock ownership, fertilizer and manure types applied, agroforestry, crops and crop production practices, access to agricultural information, farm income and marketing. Descriptive analyses of the data followed SPSS 12.0 version.

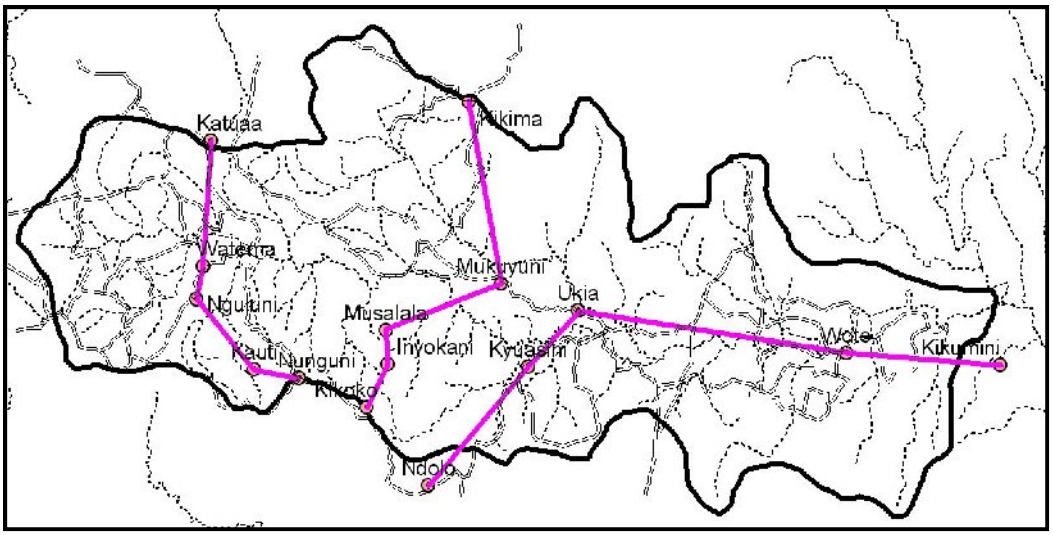


Figure 3: Transects used for data collection in Kaiti Watershed

3.0 Results

The survey revealed that Kaiti watershed residents practiced agroforestry widely. Respondents identified 16 tree species growing on their farms (Figure 4 and 5). Mango (*Mangifera indica* L.) and avocado (*Persea americana Miller*) were the most important trees followed by citrus (*Citrus* spp.), and papaya (*Carica papaya*) while loquat (*Eriobotrya japonica*), guava (*Psidium guajava*), custard apple (*Annona reticulata*) and croton (*Croton megalocarpus*) were of minor importance. Among the non-fruit trees, eucalyptus (*Eucalyptus* spp.) was the most important (Figure 5), closely followed by grevillea (*Grevillea* spp.) and neem (*Azadirachta indica*). Other non-fruit trees found were cypress (*Cupressus* spp), red pod terminallia (*Terminalia brownii*), acacia, (*Acacia* spp), wattle (*Acacia mearnsii*) and pine (*Causarina* spp). Mango was the most important tree in three of the five divisions (Kalama, Kee and Wote) closely followed by avocado. In Kilungu, Eucalyptus and avocado were the most important trees while mango and avocado were most abundant in Kaiti (Figure 6).

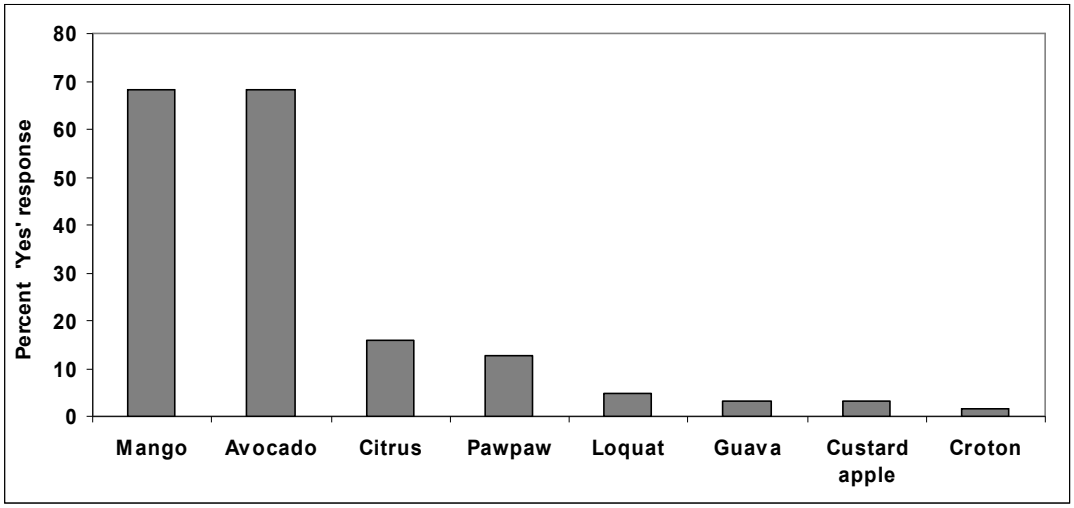


Figure 4: Prevalence of fruit trees in Kaiti watershed farms

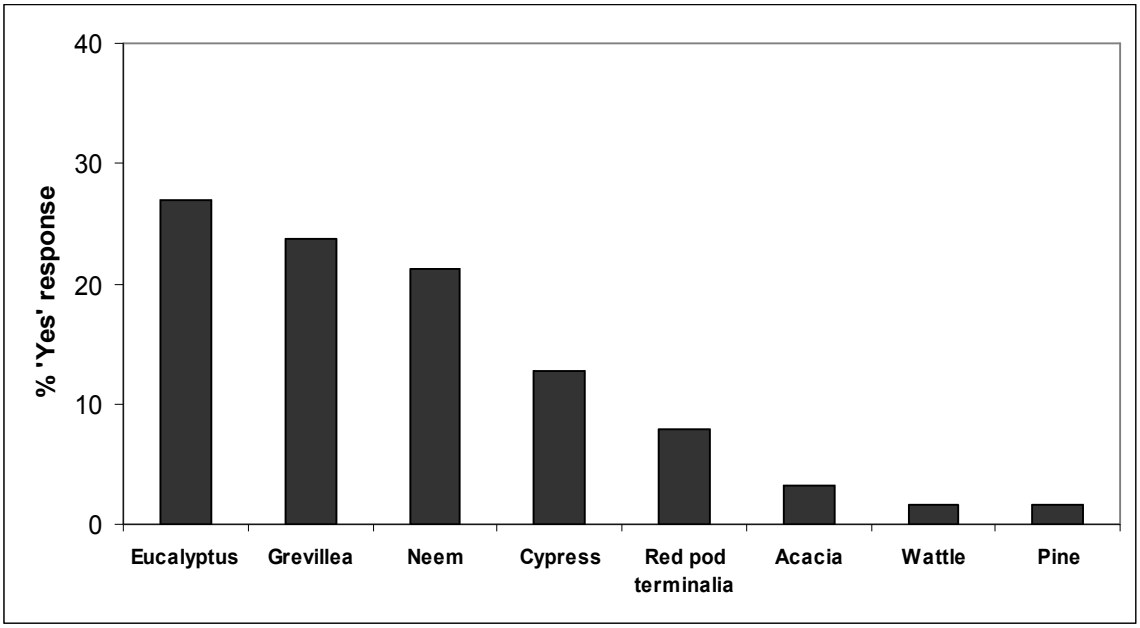


Figure 5: Prevalence of non-fruit trees in Kaiti watershed farms

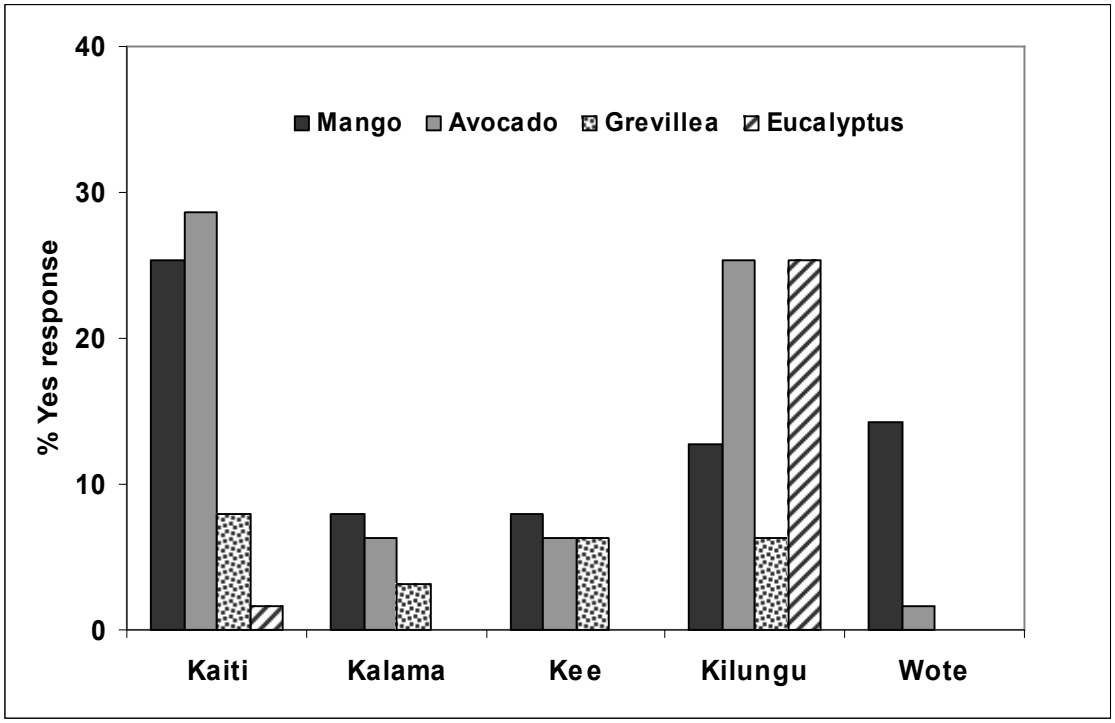


Figure 6: Occurrence of important fruit and non-fruit trees in Kaiti watershed

More than 80% of the residents in Kaiti utilized trees for food and fuel (Table 1). Trees were also used for construction (38%), fencing (29%), medicinal purposes (19%), bee keeping (4.8%) and soil fertility improvement (1.6%). Whereas utilization of trees for food and fuel occurred throughout the watershed, only the residents of Kee, Kaiti and Wote utilized agroforestry products for medicinal purposes. Only the

residents of Kilungu and Kaiti utilized trees for bee keeping and only those in Kee exploited agroforestry for soil fertility improvement.

Table 1: Utilization of trees by residents of Kaiti watershed

Utilization of agroforestry trees	Kaiti	Kalama	Kee	Kilungu	Wote	Kaiti watershed % of total
	----------Percent within division----------					
Food	30.2	7.9	6.3	23.8	15.9	84.1
Fuel	27	6.3	7.9	28.6	12.7	82.5
Fencing	9.5	0	1.6	15.9	1.6	28.6
Construction	11.1	4.8	4.8	17.5	0	38.2
Medicine	4.8	0	4.8	0	9.5	19
Bee keeping	3.2	0	0	0	1.6	4.8
Soil fertility	0	0	1.6	0	0	1.6

Respondents indicated that Kaiti residents grew trees in row within crops, along the hedges or interspersed them with crops. Only the residents of Kaiti (4.8%) grew trees in the homestead (Table 2). When asked for what purpose they practiced agroforestry, the residents of Kee and Kalama indicated that they grew trees solely for subsistence (Table 3). In Wote however, 54.5% of the residents indicated that they grew trees for subsistence and for sale. The same response was given by 27% and 21% of the respondents in Kaiti and Kilungu respectively.

Table 2: On-farm location of trees in Kaiti Watershed

Where trees are grown on the farm	Kaiti	Kalama	Kee	Kilungu	Wote
	----------Percent within division----------				
Rows within crops	4.5	20.0	33.3	21.1	0
Interspersed between crops	54.5	60.0	0	36.8	63.6
Along hedges	36.5	20.0	66.7	42.1	36.4
Homestead	4.5	0	0	0	0
Total	100	100	100	100	100

Table 3: Reasons given for agroforestry practice in Kaiti Watershed

Reasons for growing trees	Kaiti	Kalama	Kee	Kilungu	Wote
	----------Percent within division----------				
Subsistence	68.2	100	100	68. 4	36.4
Cash earner	4.5	0	0	10.5	9.1
Subsistence and cash earner	27.3	0	0	21.1	54.5
Total	100	100	100	100	100

When asked about income generation, most (80%) respondents in Kaiti, Kalama and Kilungu said that they earned a meager income (KES $\leq$5000 yr^{-1}) from the sale of trees and tree products (Table 4). Income generation from agroforestry was most important in Wote and Kilungu where 18% and 16% of the residents respectively earned KES >5000 annually while 9% of the residents earned KES > 10,000 annually. The study also reveled that record keeping followed income generation. The higher the income

from the sale of trees and tree products (e.g., in Kaiti and Kilungu), the greater was the tendency to keep records.

Table 4: Income generated from agroforestry in Kaiti watershed

Income from sale of trees	Kaiti	Kalama	Kee	Kilungu	Wote
	----------Percent within division----------				
KSh 5,000 or less	86.4	80.0	50	79.0	45.5
KSh 5001-10,000	0	0	0	15.8	18.2
>10000	9.1	0	0	0	0
No records	4.5	20.0	50.0	5.2	36.4
Total	100	100	100	100	100

Throughout the watershed, respondents indicated that they depended mostly on themselves or other farmers for information on agroforestry (Table 5). Contact with extension was absent in Kalama and Kee and minimal in Kaiti (14%) and Kilungu (11%). Only the residents of Wote had had considerable contact with extension (36%).

Table 5: Sources of agroforestry information in Kaiti Watershed

Information source	Kaiti	Kalama	Kee	Kilungu	Wote
	----------Percent within division----------				
Other farmers	40.9	40.0	16.7	68.4	0
Extension	13.6	0	0	10.5	36.4
Myself	40.9	60.0	83.3	21.1	63.6
No information	4.6	0	0	0	0
Total	100	100	100	100	100

3.1 Discussion

This survey established that agroforestry was widely practiced by farmers in Kaiti watershed (Figure 4). Agroforestry in Makueni district had had a long history in the watershed. Several projects had been undertaken between 1970 and 2000 (Gichuki, 2000c), all aimed at reducing encroachment into protected forest areas by producing tree products from non-forest resources. These projects promoted on-farm wood and non-wood production (Gichuki, 2000c). A stakeholder workshop held before the start of the project in Kaiti watershed reported that Eucalyptus was introduced before the 1960s for timber, avocado, mango and citrus for fruit in the 1970s and 1980s and Grevillea for timber and firewood in the 1980's (Muriuki, 2004). However, this survey established that fruit trees were more popular than non-fruit trees (Figure 4 and 5) indicating that fruits formed an important part of the food consumption systems in this semi-arid watershed. Indeed, consumption of fruits comes as a key survival strategy during periods of severe drought in arid and semi-arid areas (ASALs). During the severe drought of 2009 experienced in many parts of the country, consumption of wild fruits and dry carcasses was one strategy that communities used to cope with the severe famine situation experienced (Standard, 2009). Unfortunately, only a handful of Kaiti residents grew indigenous fruits trees like loquats, guava and custard apple (Figure 4). These indigenous fruit trees are naturally adapted to growing in ASALs and are highly nutritious as well. The guava for example contains 183 mg Vit. C 100 g^{-1} of fruit and is recognized one of the richest sources of vitamin C (www.naturalhub.com). Farmers should be encouraged to grow

more indigenous fruit trees to mitigate the impacts of climate change in ASALS, to generate income and to increase food and nutrition security. Climate change experts predict that ASALs in Kenya will bear the brunt of climate change impacts in the coming decades (De Wit, 2006). This calls for commercialization to access high value markets and research to breed high yielding genotypes. Guava is particularly attractive because it is not only naturally adapted to growing in semi-arid areas, it is also highly nutritious.

This survey also revealed that Kaiti watershed residents depended mostly on themselves or their neighbors for information on agroforestry (Table 5). Contact with extension was minimal in all other areas (< 15%) except Wote (36%). Residents said that they incorporated trees on-farm by planting them in rows within crops, along the hedges or by interspersing them with crops (Table 2). There were no stand alone areas devoted to trees (forests) indicating that land pressure was high. The majority of farmers practiced agroforestry for subsistence, and a lesser number, to earn cash in addition to meeting their subsistence requirements (Table 3). Eighty percent of the farmers in Kaiti, Kalama and Kilungu said that they earned KES $\leq$5000 annually from the sale of trees and tree products (Table 4), but used the trees and tree products for food, fencing, construction and firewood (Table 3). Only few farmers ($\leq$10%) grew trees solely for income generation, as returns were low (Table 4). Low income generation from the sale of trees and tree products may be explained in two ways: First, owing to the long history of agroforestry in the watershed (Gichuki 200c), most farmers had their own trees (Figure 4) so they did not need to buy from neighbors and secondly, disposable incomes were low and mostly devoted to purchasing food at the expense of other needs (Mbogoh, 2000).

4.0 Conclusions

Whereas agroforestry was widely practiced in Kaiti watershed, most residents relied on themselves or their neighbours for information on agroforestry. Trees were most frequently found growing along hedges or interspersed them between crops. Earnings from agroforestry were low, so products were mostly used for subsistence. Fruit trees were more abundant than non-fruit trees and indigenous fruit trees though locally adapted and highly nutritious were few. It therefore seems that future agroforestry efforts in Kaiti watershed should focus on research and commercialization of indigenous fruit trees so as to enhance food and nutrition security, generate income and mitigate the impacts of climate change.

References

Anonymous. Food security district profile: Makueni district, Eastern province. http://www.kenyafoodsecurity.org/images/stories/files/dps/eastern/kakueni.pdf. Accessed 25th July 2010.

De Wit, M. (2006). Climate change and African agriculture. Policy Note No. 12 CEEPA, University of Pretoria.

Gichuki, F.N. (2000a). Makueni district profile: Farm development, 1946-1999. *Drylands research working paper 1*. Drylands research, Crewkerne, UK.

Gichuki, F.N. (2000b). Makueni district profile: Soil management and conservation, 1989-1998. *Drylands research working paper 4*. Drylands research, Crewkerne, UK.

Gichuki, F. N. (2000c). Makueni district profile: Tree management, 1989-1998. *Drylands research working paper 5.* Drylands research, Crewkerne, UK.

Gichuki, F., Mbogoh, S., Tiffen, M. and Mortimore, M. (2000). Makueni district profile: Synthesis. *Drylands research working paper 11*. Drylands research, Crewkerne, UK.

Jaetzold, R., and Schmidt, H. (1983). Farm management handbook of Kenya, Vol. IIC Eastern Province. Natural conditions and farm management information. Ministry of Agriculture, Nairobi, Kenya.

Mbogoh, S. (2000). Makueni District Profile: Crop production and marketing (1988-1999). Drylands research working paper 7. Drylands research, Crewkerne, UK.

Mbuvi, J. P. (2000). Makueni district profile: Soil fertility management. Drylands Research Working paper 6. Drylands research, Crewkerne, UK.

Muriuki, A. W. (2004). Soil Fertility and Agricultural productivity in Makueni District: A Closer Look. Paper presented during the Stakeholder workshop held at Precious Blood Secondary School, Kilungu, Makueni, Kenya. 22nd -23rd, December 2004.

Kaluli W., Muriuki, A. and Gathenya, M. (2005). The potential for irrigation development in water-scarce watersheds: Kaiti water catchment case study. Paper presented during the East Africa Regional Workshop on Management of Irrigation & Drainage Research, Morogoro, Tanzania. 6th – 8th December 2005.

The Standard (May 29, 2009). Kenya Red Cross Society: Drought operations response, 2009.

http://212.22.182.205/redcross/images/pdf%27s/Drought_Appeal_Supplement_May_2009.pdf

www.naturalhub.com (2010). Natural food-Fruit Vitamin C Content. http://www.naturalhub.com/natural_food_guide_fruit_vitamin_c.htm. Accessed 25th July 2010.

TRENDS, RATES, CAUSES AND IMPACTS OF LAND USE/COVER CHANGES IN RIVER BUATHONARO CATCHMENT IN MERU COUNTY, KENYA

C. Ngeera[1], J. M. Gathenya[2] and P.G. Home[3]
Biomechanical and Environmental Engineering Department, Jomo Kenyatta University of Agriculture and Technology, Nairobi,Kenya
E-mail: ngeerac@yahoo.com

Abstract
The rates and trends of LUC changes in River Buathonaro catchment were analyzed from orthorectified multi-temporal Landsat imageries of 1979 and 2000. The images were classifies into four broad LUC classes using supervised classification method. The results show in the period 1979-2000, forests reduced by 33%, agriculture increased by 11 %, open woodland/pasture and built-up area increased by 14% and 8% respectively. The major driving forces for LUC change were found to be agricultural expansion, deforestation, infrastructural development driven by economic, demographic and social/cultural factors. In light of the deteriorating environmental conditions, especially declining water resource in the catchment, there is an urgent need to halt the environmental degradation and destruction.

Key words: Land use/cover, Buathonaro catchment, remote sensing, landsat images, change detection, Kenya

1.0 Introduction

Changes in land use/cover have been recognized since the mid 80s as an important factor of the global environmental change (Turner, 2002). Calls for substantive studies of land use/cover changes were made during 1972 Stockholm Conference on the Human Environment, and again 20 years later, at the 1992 United Nations Conference on Environment and Development (UNCED)

Land use/cover (LUC) change is an important process affecting both natural and human environment through many ecological and socio-economic impacts (Mandelas *et al,* 2007) because of this, LUC changes are now central issues in many political and natural resources disputes (Goetz, *et al.,* 2003).This paper adresses the dynamics of LUC changes and their impacts on the natural environemt of River Buathonaro catchment.

LUC information provides means of discerning and analyzing geospatial relationships between the socio-economic trends, change drivers, and impacts on the environment (Lambin *et al.,* 2001).Globally there are two main causes of LUC changes bio-physical and socio-economic (Geist, 1999). The bio-physical drivers include the phenomena of the natural environment while socio-economic drivers comprise of social –economic factors. Socio-economic factors are further divided into proximate and underlying factors (Lambin *et al.,* 2001).

LUC changes impacts natural ecosystems and their functions in many ways, the most common effects are on soil, water resources and on biodiversity (Eswaran *et al.,* 2001). The most severe impacts on soil resources are: depletion of soil organic matter, and consequent loss of fertility, erosion and desertification; and biological degradation. Water resources suffer degradation of the quality and quantity while biodiversity degradation results in loss of flora and fauna.

With LUC changes having significant effects on ecosystems and their ability to support societal needs, understanding LUC dynamics and their impacts has been recognized as key research imperative in environmental studies (Turner *et al.,* 1990; Turner and Meyer 1994; Lambin *et al.,* 1999; Geist, 1999; Lambin *et al.,* 2001).

LUC mapping is now a standard way of monitoring dynamics of LUC changes (Rogana and Chen, 2004). The mapping is now easily and cheaply done using RS and GIS, which have gained much recognition as environmental resources management tools for data collation and analysis (Geist and Lambin 2002). Remote sensing provides high spectral, spatial and temporal resolution data that is used to characterize landscapes and quantifying changes (Rindfuss *et al,* 2004).

To detect LUC changes, a comparison of two or more satellite images acquired at different times is done to evaluate the temporal or spectral reflectance differences that have occurred between them (Yuan and Elvidge, 1998).Change detection analysis is then performed to determine the LUC changes over time and space. The results are presented in a spatio-temporal framework that can be used as inputs to many other uses that have links with space such as water management, deforestation, and land degradation among others.

In Buathonaro Catchment intensive (and extensive) process of land LUC changes occurred since the 70s.Because of these changes, attention has been drawn to the issues of LUC changes, their causes and the relationships these changes might be having on observed environmental degradation in the catchment. The aim of this study was to analyze the spatio-temporal land use/land cover change patterns dynamics using multi temporal Landsat imageries covering a span of twenty one years (1979-

2000).The specific objectives were to map and determine the nature, extent and rate of LUC change, and to investigate the LUC impacts on environmemt

2.0 Materials and Methods

2.1 Description of the Study Area

The River Buathonaro catchment is 150 Km^2 and lies between approximately 2,050 m above sea level in the upper sections and about 700 m above sea level in the lower parts. The catchment is bounded by latitude 37° 53| 00|| E and 38° 05| 00|| E and 0° 12| 00|| N and 0° 21| 00|| N,(Figure 1).

The catchment contributes to maintenance of water resources, agriculture, forestry and tourism development.The altitude ranges from 2060 M a.s.l to 700 M a.s.l the climatic conditions range from humid to semi-humid. Rainfall is bimodal coming during the long rainy season of March to May and the short rainy season from October to December. The mean annual rainfall range between 1000mm and 1500mm.

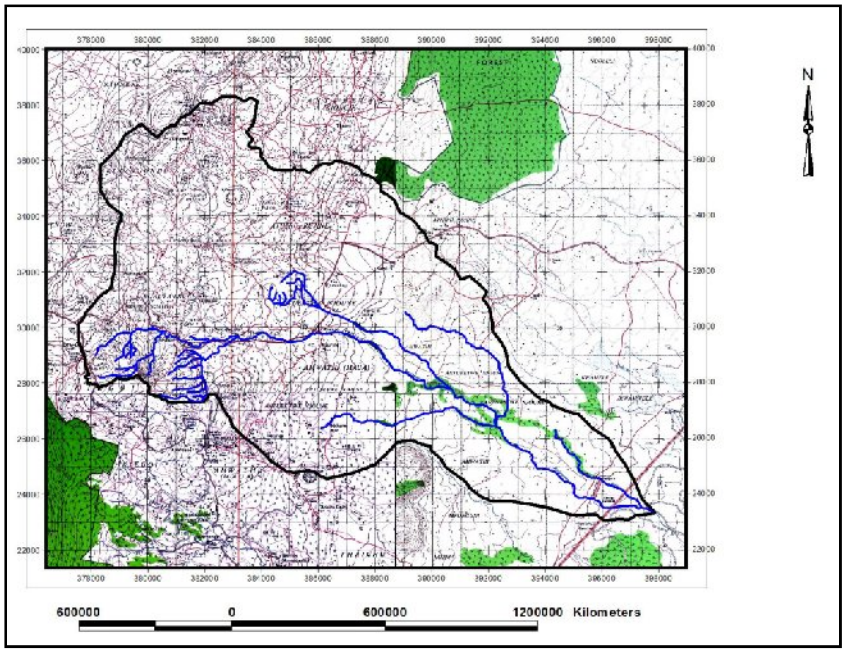


Figure 1: River Buathonaro catchment

2.2 Land Use/Cover Classification

A classification scheme comprising of four LUC types was developed for the purpose of this study (Table 1). A multilevel, hierarchical LUC classification was derived from the priori knowledge of the study area, and a GPS aided reconnaissance survey. The classification scheme was based on Anderson, (1979) hierarchical classification system used in classification of satellite images.

Table 1: Land use /cover classification scheme

Level I	*Level II*
Forest	Forests cover on hills and along the river banks
Agriculture	Subsistence mixed farming
	Tea plantations
Open woodland/Pasture	Pasture with scrubs and grass pastures
	Scattered trees
Built-up area	Human settlement, Roads and Market centres

2.3 Remote Sensing Data Processing

Landsat Multispectral Scanner (MSS), Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) images (path 168, row 60) were used in this study. The Landsat images were downloaded from USGS Earth Resources Observation Systems data centre.

The images were processed using remote sensing software ENVI version 4.0.The images were false colors composites formed from Landsat bands ideal for analyzing LUC change in tropics as stated by Prakash and Gupta (1998). The area under the catchment was sub-set for fast processing using Arcview shapefiles of the study area.

Image classification was done using the standard methods described by Lillesand and Kiefer (2004).Training sites used for classification were determined using supervised classification aided by the classification scheme developed during fieldwork, ground survey and GPS points. The classification was performed using the maximum likelihood classification algorithm which is the most accurate of the classification algorithm (Lillesand and Kiefer 2004).

A standard accuracy assessment procedure involved the use of the error matrix (Fan, 2007; Stehman, 1997). Overall accuracy, user's and producer's accuracies, and the Kappa statistic were then derived from the error matrix. This study used post classification technique to compare the areas covered by each LUC class in 1979 and 2000 and to determine directions of the changes (positive or negative).

2.4 Questionnaire Interview

The questionnaires employed in this study involved discussion of three main topics which includes past and present land use and land covers; impacts of the LUC changes; and causes of land use changes. The questionnaires included both open-ended and close-ended questions. The open-ended questions gave the respondents an opportunity for self-expression to share their views, experiences and opinions.

3.0 Results and Discussion

3.1 Classification Accuracy Assessment

Evaluation of classification results is an important process in satellite image classification procedure. Confusion/error matrx is the most commonly employed approach for evaluating per-pixel classification (Lu and Weng, 2007). The resulting Landsat LUC maps of the three periods of 1979 and 2000 had an overall map accuracy of 65% and 69.5 % respectively. These accuracies were reasonably good and accepted for the subsequent analysis and change detection.

3.2 Nature, Extent and Rate of Land Cover Change Maps and Statistics

Land use/cover maps were generated for the two periods studied (Figure 2 and 3), the major land cover classes identified were agriculture, built up areas, forest and open woodland/pasture).

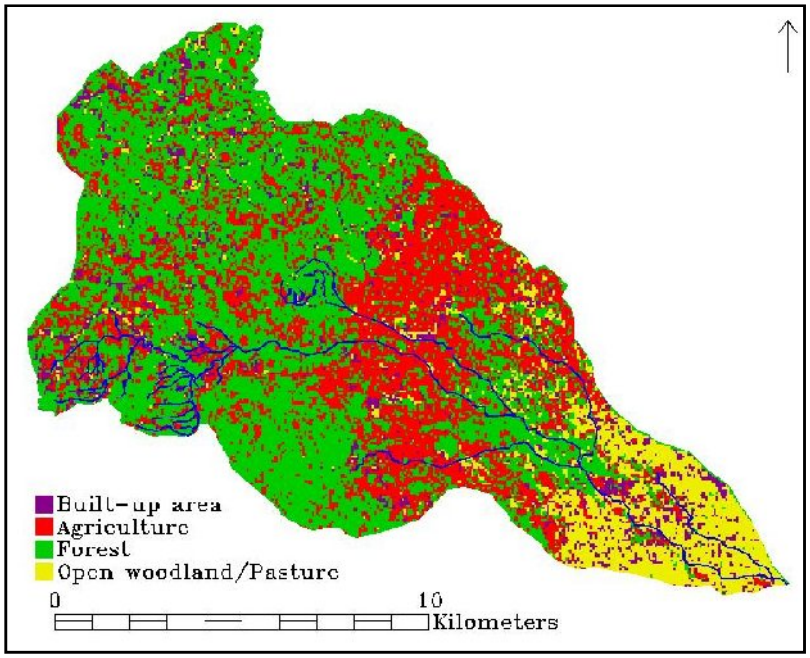


Figure 2:The 1979 LUC classes of River Buathoanro catchment

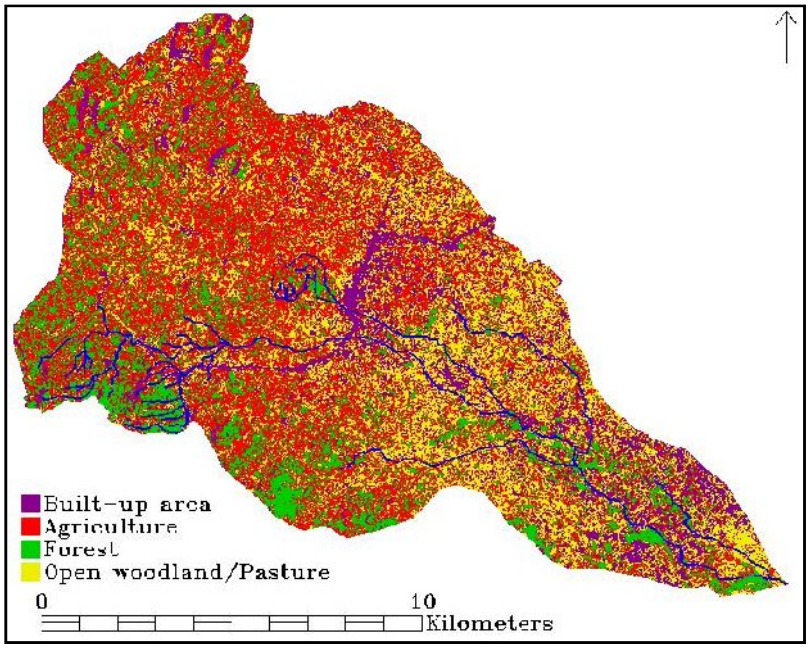


Figure 3: The 2000 LUC classes of River Buathoanro atchment

Individual class area and change statistics for the two periods were summarized inTable 1 and Figure 4.

Table 1: Land use/ cover changes from 1979 to 2000 in Buathonaro Catchment

LUC class	LUC change (total area coverage (Km^2) and their percentage)				Changes in LUC in percentage	
	1979		2000		1979-2000	Changes per year
	Area	%	Area	%	%	%
Forest	74.9	49	25.0	16	-33	-1.57
Agriculture	47.7	31	63.4	42	+11	+0.52
Built-up area	10.7	7	22.6	15	+8	+0.38
Open wood/pasture	16.74	11	39	25	+14	-0.67

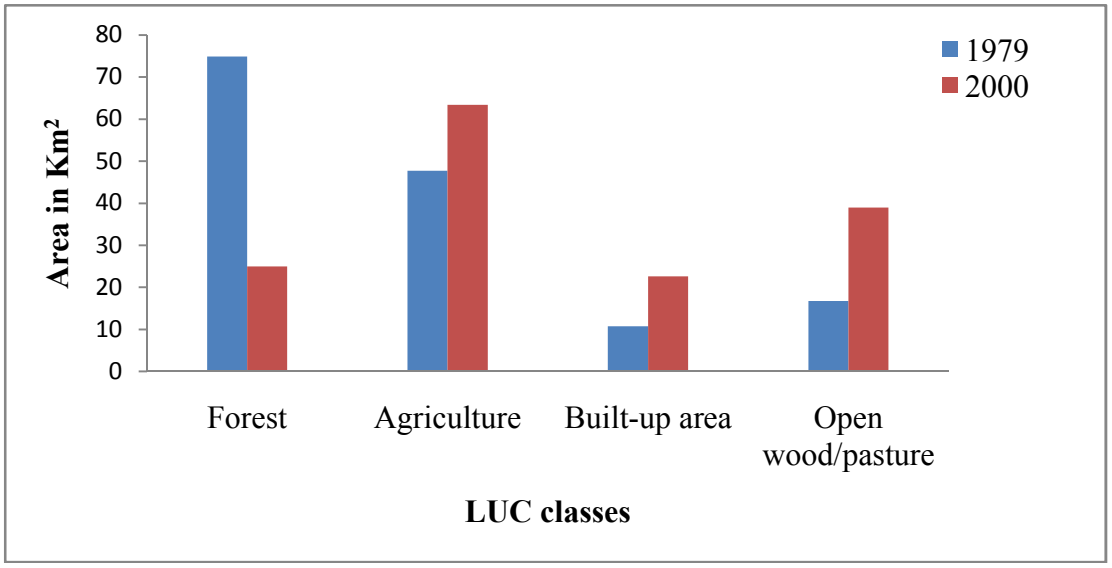


Figure 4: Comparison of LUC classes in 1979 and 2000

3.3 Causes of LUC Changes

With agriculture covering the largest area of the catchment in 2000, this implies that agricultural area has been expanding faster than other LUC types. Expansion of agriculture has greatly contributed to the LUC change in the catchment. Agriculture has lead to deforestation and encroachment on forests for farming and settlements. It was observed during the field work that agriculture was expanding to steep hills sides, wetlands, and on river valleys. As noted by Lambin and Geist (2001) smallholder subsistence tends to be a robust cause of LUC change, being about three times more often associated with the expansion of agriculture.

Demographic changes especially, population growth and migration have caused the LUC changes in the catchment. Though there were no figures to show the population growth in the catchment, the population of Meru County has grown significantly since 1979. Population growth is widely recognized as a key force behind LUC changes, especially in developing countries (Lambin *et al.,* 2001). The population increase in the catchment led to increased pressure on land, leading to the LUC changes

Economic factors especially the growth of lucrative Khat (*Catha edulis*) market has made many farmers convert their fields and clear more forested area to grow Khat. The other economic factor is poverty, which has lead to diversification of livelihoods through selling of firewood and timber; this explains the

other reason rapid deforestation in the catchment, especially along the fringes of the two main wetlands.

Infrastructural growth and improved road network along the catchment increased accessibility of the areas. Alves (2002) showed that infrastructural growth can lead to drastic changes in LUC. The study showed that deforestation is concentrated around major roads and pioneer settlements In addition; there was rapid development of shopping centers along the main roads.

3.4 Impacts on the Natural Environment

The major environmental degradation in the catchment attributable to LUC changes include loss of wetlands and springs and land degradation. Current there are concerns about the declining quantities and quality of the water resources caused by the rapid LUC changes especially in the head water areas of the catchment. This problem is further aggravated by the conversion of wetlands into farm land.

The two main wetlands in the Athindi and Mporoko have been converted into agriculture. Sixty per cent of the original 60 acres of Athindi is now under agriculture, while only fifty per cent of the 130 acres of Mporoko is natural habitat. Currently out of the fifty nine permanent springs in 1979 only thirty two are remaining.

Land degradation has also occurred in the catchment, the factors initiating land degradation as mentioned (Lal, 1994) are evident in the catchment. These factors include physical, chemical, and biological processes. The physical and chemical processes of land degradation are manifested by soil erosion and formation of deep gulleys. Biological factors include decline in land biodiversity caused by clearing of forests and wetland habitats.

4.0 Conclusion

Results of this study show that River Buathonaro catchment has undergone LUC changes as a result of human activities. The changes are degrading the natural environmental especially the water resources. Therefore, there is an urgent need to stop further degradation by rehabilitating damaged ecosystems and advocating for sustainable land use practices. Lastly, there should be efforts to continuously collection socio-economic and environmental data for constant monitoring of the state of environment.

Acknowledgement

We gratefully acknowledge the help of Mr. Philip Ogweno Jomo Kenyatta University of Agriculture and Technology in analysis of the RS images and the questionnaires.

References

Amazon in the Period 1991-1996. In Deforestation and Land Use in the Amazon, edited by C. H. Wood and R. Porro. Gainesville: University Press of Florida.

Anderson, J. R. (1977). Land use and land cover changes-A framework for monitoring: US Geol. *Survey, Jour. Research*, **5**(2) pp. 223-224.

Anderson, J. R. (1977). Land use and land cover changes-A framework for monitoring: US Geol. *Survey, Jour. Research*, **5**(2) pp. 223-224.

Fan, F., Weng, Q. and Wang, Y. (2007). Land use land cover change in Guangzhou, China, from 1998 to 2003, based on Landsat TM/ETM+ imagery. *Sensors*, **7**, pp 1323-1342.

Geist, H. (1999). Exploring the Entry Points for Political Ecology in the International Research Agenda on Global Environmental Change. – Zeitschrift für Wirtschaftsgeographie, **43** (3/4), pp. 158-168.

Geist H. J. and Lambin E. F. (2002). Proximate Causes and Underlying Driving Forces of Tropical Deforestation. *BioScience,* **52**, pp. 143-150

Goetz, S. J., Smith, A. J., Jantz C., Wright, R. K., Prince, S. D., Mazzacato, M. E. and Melchior, B.,(2003) Monitoring and predicting urban land use change: Application of multi-resolution multi-temporal satellite data. IGRASS'03 proceedings. 2*003 IEEE International,* Vol.**3** pp.1567-1569.

Jensen, J. R. (2004). Introductory digital image processing: A remote sensing perspective; Prentice-Hall: New Jersey, pp 526.

Lal, R. (1994). Tillage effects on soil degradation, soil resilience, soil quality, and sustainability. *Journal of Soil Tillage Research,* **27**, pp 1–8.

Lambin, E. F., Turner, B. L. II, Geist, H. J., Agbola, S. B., Angelsen, A., Bruce,J. W., Coomes, O., Dirzo, R., Fischer, G., Folke, C., George, P. S., Homewodd,K., Imbernon, J., Leemans, R., LI, X., Moran, E. F., Mortimore,M., Ramakrishnan, P. S., Richards, J. F., Skånes, H., Steffen, W., Stone,G. D., Svedin, U., Veldkamp, T. A., Vogel, C. and XU J. (2001). The Causes of Land-Use and Land-Cover Change. Moving Beyond the Myths. – Global Environmental Change: Human and Policy Dimensions. Vol. **4.**

Lambin, E. F., Baulies, X., Bockstael, N., Fischer, G., Krug, T., Leemans, R.,Moran, E. F., Rindfuss, R. R., Sato, Y., Skole, D., Turner, B. L. Ii and Vogel C. (1999). Land-Use and Land-Cover Change (LUCC) – Implementation Strategy. Acore project of the International Geosphere-Biosphere Programme and the International Human Dimensions Programme on Global Environmental Change (= IGBP Report;48/IHDP Report; 10). – IGBP Secretariat: Stockholm and IHDP Secretariat: Bonn.

Lillesand, T, M. Kiefer, R. W. and Chipman, J. W., (2004). Remote sensing and Image interpretation. Fifth edition. John and Sons, Inc. New York. 828 p.

Lu, D. and Weng, Q. (2007). A survey of image classification methods and techniques for improving classification performance. *International Journal of Remote Sensing*, Vol. **28**(5), pp.823-870.

Lu, D. Mausel, P. Batistella, M. and Moran, E. (2005). Land-cover binary change detection methods for use in the moist tropical region of the Amazon: a comparative study. *International Journal of Remote Sensing*, **26**(1), pp 101–114.

Mandelas, A. E, Hatzichristos T. and Prastacos P.(2007). A fuzzy cellular automata based shell for modeling urban growth- a pilot application in Mesogia area, 10th AGILE International Conference on Geographic information Science, 2007, Aalborg University, Denmark.

Mas, J. F. (1999). Monitoring land-cover changes: a comparison of change detection techniques. *International Journal of Remote Sensing*, **20**, pp 139–152.

Muttitanon, W., and Tripathi, N. K. (2005). Land use/land cover changes in the coastal zone of Ban Don Bay, Thailand using Landsat 5 TM data. International Journal of Remote Sensing, **26**(11-10), pp 2311-2323.

Prakash, A. and Gupta, R. P. (1998). Land-use mapping and change detection in a coal mining area. A case study in the Jharia Coalfield, *India.int.j.remote sensing*, **19**(3), pp 391- 410.

Rindfuss, R. R., Walsh, S. J., Turner, B. L., Fox, J., and Mishra, V. (2004). Developing a science of land change: challenges and methodological issues. Retrieved on the 4th of May, 2007 from http://www.pnas.org/cgi/reprint/101/39/13976

Rogana, J and Chen D. (2004). Remote sensing technology for mapping and monitoring land-cover and land use change, *Progress in Planning,* **61**, pp 301-325.

Turner, B. L. Ii and Meyer W. B. (1994). Global Land-Use and Land-Cover Change: An Overview. – in: MEYER, W.B. & B.L. TURNER II (Eds): Changes in Land Use and Land Cover: A Global Perspective. – University of Cambridge: Cambridge, New York, Melbourne, pp. 3-10.

Turner, B. L. Ii, Clark, W. C., Kates, R. W., Richards, J. F., Mathews, J. T. and Meyer W.B. (Eds; 1990): The earth as transformed by human action. Global and regional changes in the biosphere over the past 300 years. - Cambridge University Press (with Clark University): Cambridge, New York, Port Chester, Melbourne and Sydney.

Turner B.L. (2002). Toward Integrated Land-Change Science: Advances in 1.5 decades of Sustained International Research on Land-use and Land-cover Change. **In**: Erika L., Eric F, et al., (Eds.).A Synthesis of Information on Rapid Land-Cover Change for the Period 1981-2000.*Bioscience,* **55**, pp.115-124.

Yang, X. (2002). Satellite monitoring of urban spatial growth in the Atlanta metropolitan area. *Photogrammetric Engineering and Remote Sensing*, **68**(7), pp 725–734.

Yuan, D, Elvidge, C. D., and Lunetta, R. S., (1998). Surveys of multispectral methods for land cover change analysis. Remote sensing change detection: Environmental monitoring methods and applications pp.21-39. Michigan: Ann Arbor Press.

STUDY OF GROUNDWATER QUALITY IN NAIROBI, KENYA

P. Muraguri[1], G. T. Thiong'o[2], J. M. Gathenya[3] and D. Olago[4]
[1]Ministry of Water and Irrigation
[2,3]Jomo Kenyatta University of Agriculture and Technology
[4]University of Nairobi

Abstract
The objective of this study was to assess the quality of groundwater in Nairobi to ascertain its quality and compare with World Health Organization (WHO) drinking water standards. Water samples were obtained during the wet and dry seasons from thirty boreholes, distributed in six administrative zones (A to F) of Nairobi, nemelt, Kasarani/Roysambu area (Zone A), Dagoretti/Kawangware area (Zone B), Embakasi area (Zone C), Karen/Langata area (Zone D), City Centre area (Zone E) and Industrial area (Zone F) according to land use. Physical parameters varied; total dissolved solids; 207-688 mg/L, turbidity; 1.7-19.7 N.T.U., conductivity; 0.32-0.99 µS/cm, temperature; 22.8-27.3^{o}C and colour; <5-5 TCU. pH; 5.7-8.8 and chemical parameters also varied; 9.6-44.8 mg/L, Zn; 0.01-0.38, Cd; 0.00-0.03, Cu; 0.0-2.6, Ni; 0.024-0.38, Cr; 0.0-0.49 and Pb; 0.11-0.30, As; 0.00-0.013 and Hg; 0.001-0.003 all in ppm. The parameters that were measured, namely, total dissolved solids (TDS), turbidity, conductivity, pH, as well as the heavy metals Zn, Cd, Cu, Ni, Cr, Pb, As, and Hg all varied widely. TDS, total hardness, Zn and Hg were within the WHO consumers' acceptable limits. The highest pH mean value of 8.75 was recorded from Karen/Langata area. Cu was found to be below detection limit except for two boreholes in industrial area (A.C 29 and F.E.30) which were above WHO limits during the wet season. High levels of Cd and Cr were detected in boreholes in zones A, B and F during the dry season with zone B recording the highest mean value of 0.03±0.01 ppm and 0.49±0.02 ppm of Cd and Cr respectively. Arsenic was within WHO standards for most sampled boreholes except for boreholes E.A.21 and M.W.25 in the city centre. All the sampled boreholes gave high concentrations of Ni during the dry season and Pb during the two seasons which were above WHO drinking water standards. The results suggest that groundwater from Nairobi boreholes need to be treated so that the water could meet WHO drinking water standards. Plain sedimentation or use of cloth/membrane filters may be used remove turbidity while reverse osmosis could be one of the appropriate methods for water treatment that could beA used where heavy metals are present.

Key words: Groundwater quality, heavy metals, Nairobi, Kenya

1.0 Introduction

The population of Nairobi is approximately 3.14 m according to 2009 population census (CBS, 2010). Nairobi is one of the regions where limited natural resources and services are facing relentless pressure due to rapid population growth and water is not exempted. The increased demand for housing has resulted in mushrooming unplanned settlements and slums that do not have adequate, or lack, water supply and sanitation services. Consequently, inhabitants in several parts of Nairobi have had to increasingly rely on groundwater as their sole or supplementary source of portable water, and industries are also increasingly exploiting this resource.

Groundwater extraction from wells and boreholes in Nairobi began in the 1930s: the number of water wells in Greater Nairobi increased from less than 10 in 1940 to almost 2000 in 1997 and further increased to 2250 in 2001 as a result of the drought, and today number over 2500. The amount of groundwater abstracted has steadily increased to an estimated 85 Ml/d (85,000 m^3/d) in 2002, which amounts to 25% of the overall water-supply of the population of Greater Nairobi. Other than the increasing demand due to population and industrial growth, the pollution of surface water is a key driver of the increasing extraction of groundwater. Water supply and management in urban areas is complicated not only by increases in population, but also due to the nature of urbanization itself. The large number of multiple pollution sources (e.g. sewers/latrines, cemeteries, domestic waste, landfill, etc.) found in urban areas complicate urban groundwater protection through leachate dispersal to groundwater aquifers (Michael, 1994). The multiple pollution sources are compounded by variable dynamic distributions in hydraulic head due to complex abstraction patterns and often a multitude of abandoned boreholes in urban areas (Cronin et al., 2003). In addition to these technical problems, there are socio-economic issues such as under-investment in the infrastructure needed for water provision (Sinclair, 2000).

Groundwater may also become contaminated due to improper disposal of liquid wastes, defective well construction and failure to seal the abandoned wells. These provide openings for the downward movement of water into subsurface formations without the process of natural infiltration. Contamination may also take place through the movement of waste water through large openings such as animal burrows, fissures in rocks, coarse gravel formations or man-made excavations (Raghunath, 1987). Excessive pumping or over pumping may draw waters with different composition towards the screen and cause mixing of waters (Appelo and Postma, 1996). Heavy metals are dangerous because they tend to bioaccumulate. The serious arsenic contamination of groundwater in Bangladesh has recently emerged as the biggest natural calamity in the world with 75 million people at risk and 24 million potentially exposed to arsenic contamination (Talukder *et al*. 1998).

The structures in the Basement System rocks are fairly complicated while those in the volcanics are fairly simple (Fairburn, 1963; Saggerson, 1991). In the eastern part of Nairobi, faulting is rare and only minor faults were observed in the northern part of this area (Fairburn, 1963). The soils of the Nairobi area are products of weathering of mainly volcanic rocks under relatively high temperature and rainfall, good drainage prevailing in the Kikuyu Highlands in the west and poorer drainage conditions typifying the Athi Plains in the east (Saggerson, 1991). Groundwater flow is principally directed east-south-east from the main recharge area towards the Athi floodplain, where most of the groundwater formerly discharged as springs or seepages into local streams and depressions. Groundwater recharge is through infiltration and percolation from precipitation or seepage from rivers, lakes, irrigation or manmade structures (Freeze and Cherry, 1979; Larsson, 1984). The recharge points of Nairobi area are at Ngong, Kikuyu and Tigoni. The recharge of the free groundwater appears to be adequate but the confined aquifers have suffered loss of storage at localities of continuous large abstraction (Ruaraka, Kahawa, Athi River Station

(Gevaerts, 1964). Today, the many water boreholes in Greater Nairobi intercept most of this groundwater flow.

1.1 Study Area

Nairobi City, the capital of Kenya, is situated at an elevation of about 1661 m in the highlands of the southern part of the country with a total area of 696 km^2. Nairobi is adjacent to Kajiado to the eastern edge of the Rift Valley and neighbours Kiambu in Central province to the North, Machakos in Eastern province to the Southeast and Ngong hills to the West. Nairobi is Kenya's principal economic, administrative, and cultural center and is one of the largest and fastest growing cities in Africa. The main administrative divisions of Nairobi are Central, Dagoretti, Embakasi, Kasarani, Kibera, Makadara, Pumwani and Westlands. The Nairobi River and its tributaries traverse through the Nairobi Province.

The study area was divided into Kasarani/Roysambu area (Zone A), Dagoretti/Kawangware area (Zone B), Embakasi area (Zone C), Karen/Langata area (Zone D), City Centre area (Zone E) and Industrial area (Zone F) according to land use.

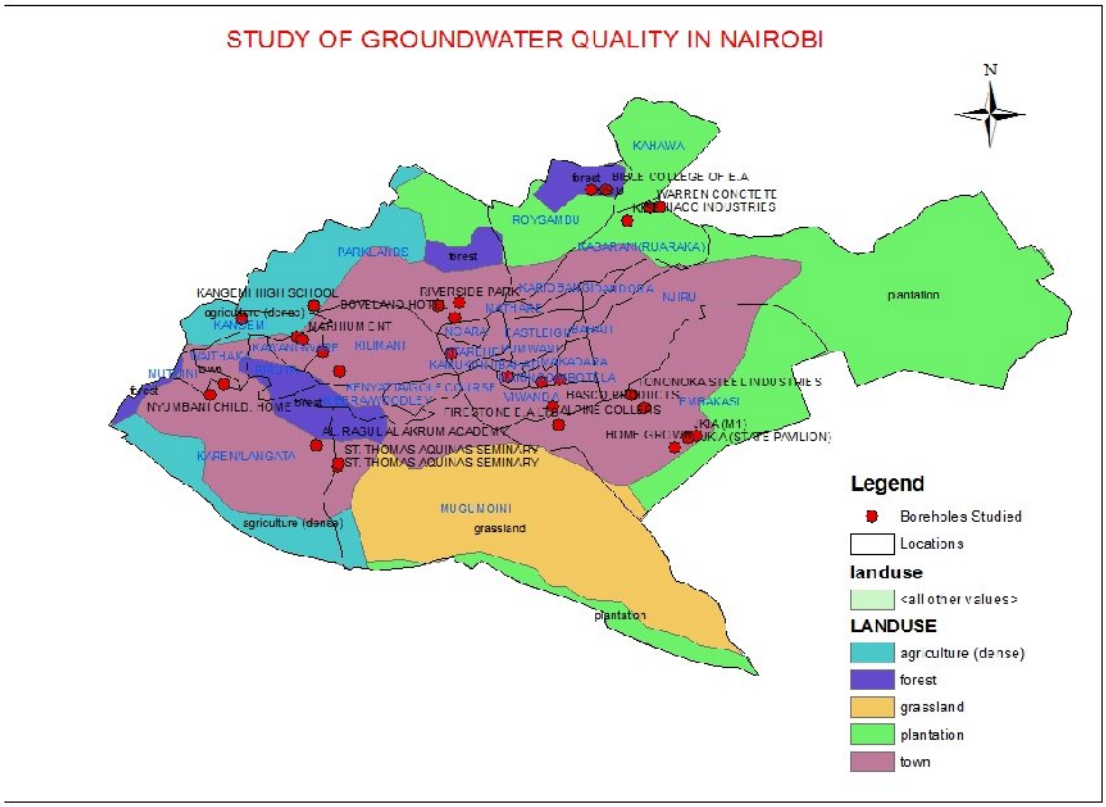


Figure 1: Administrative Map of Nairobi showing boreholes studied

2.0 Materials and Methods

Five boreholes were sampled in each of the six areas, adding up to a total of thirty boreholes. Water sampling was conducted between 26th May and 30th June, 2009 for the wet season and between 19th and 26th August, 2009 for the dry season.

Samples were taken from a pump outlet pipe through which water was in continuous flow. Thereafter, the tap was turned on fully and water was allowed to flow for two minutes before taking the sample. To prevent unnecessary aeration while the sample was being taken, the tap was turned partially open and the bottle was filled to within 15 mm of the top of the neck. The stopper was closed to make a tight seal and the bottle was properly labeled with the given code, the date and the time of sampling, and a special identifying mark for the acidified.

One sample from each collection site was acidified using 2ml concentrated nitric acid to preserve for metal analysis. Samples for laboratory analysis were filtered using a 0.45µm pore diameter and stored in a cool box set at 4^{o}C.
Conductivity, TDS, turbidity and pH were determined on site using standard methods (APHA, 1995). Zn, Cd, Hg, Cu, Ni, As, Cr and Pb were analyzed using Atomic Absorption Spectrophotometer (AAS).

3.0 Results

3.1 Physico-chemical Parameters

86.7% of the total samples had <5 true colour units. Only one borehole exceeded the acceptable guideline value of 15 TCU. The mean average temperature for the whole region was 25.3±2.5 (^{o}C

Turbidity levels were higher during the wet season (12.2.1±8.94) compared to the dry season (8.73±5.93). Highest turbidity values were recorded in zone D (19.7±5.7) and zone C (14.16±8.16) during the wet and the dry season respectively. Zone C recorded the highest TDS values during the two seasons with 687.7±206.9 and 618.2±163.3 during the wet and the dry season respectively. Conductivity values were also highest with the wet season recording 0.99±0.31 and the dry season 0.95±0.26.

pH levels of the boreholes sampled varied from borehole to borehole. On average, the dry season recorded increased acidity as compared to the wet season with zone A recording the lowest reading as low as 4.52. More than 50% of the boreholes recorded readings outside the acceptable range of 6.5–8.5 during dry season. The average pH value for the study region was 7.7±1.4 with a confidence level of 0.61 and 0.84 at 99% in wet and dry season respectively.

Table 1: Wet season values (n=30) for physico-chemical parameters at different sampling stations of Nairobi City, Kenya (May-August, 2009)

Zone:	Code	Free Turbidity (NTU)	TDS (mg/L)	Conductivity (µS/cm)	Colour (TCU)	Temp. (^{o}C)	pH (pH Scale)
Kasarani/ Roysambu	H.I.1	0.19±0.04	123.30±2.52	0.81±0.10	<5	26.37±0.06	7.18±0.02
	W.C.2	3.78±0.11	314.67±6.11	0.70±0.02	<5	28.67±0.12	8.30±0.10
	K.I.3	1.18±0.44	382.67±4.16	0.58±0.00	<5	24.1±0.66	7.93±0.35
	U.S.4	24.44±4.18	617.00±10.82	0.93±0.02	<5	28.43±0.49	6.53±0.25
	B.C.5	20.97±4.79	318.67±256.64	0.49±0.37	<5	28.67±0.12	7.57±0.35
Dagoretti/ Kawangware	M.D.6	1.61±0.42	216.67±0.58	0.34±0.03	<5	31.17±1.04	8.17±0.15
	D.C.7	0.68±0.14	179.33±0.58	0.27±0.01	<5	28.17±0.25	7.15±0.21
	D.H.8	0.79±0.77	306.33±1.15	0.46±0.01	<5	22.53±0.15	4.88±1.01
	P.B.9	2.08±0.87	161.33±3.79	0.24±0.02	<5	22.97±0.06	5.64±1.12

	M.F.10	3.23±0.26	176.33±2.52	0.28±0.02	<5	27.43±0.31	6.87±0.32
Embakasi	T.S.11	16.18±4.56	473.33±8.50	0.73±0.04	<5	24.17±2.57	5.48±0.23
	J.A.12	20.32±2.85	994.33±19.30	1.49±0.02	<5	27.57±0.23	9.11±0.46
	J.A.13	16.73±1.53	527.33±18.45	0.79±0.02	<5	27.53±0.12	8.50±1.27
	H.G.14	15.30±1.80	761.67±148.80	0.88±0.03	5.0	23.83±0.65	7.66±1.02
	B.P.15	25.17±3.75	681.67±40.81	1.08±0.04	<5	28.27±0.50	8.43±1.63
Langata/	S.T.16	18.61±5.20	217.67±1.53	0.35±0.02	<5	25.03±0.32	7.67±0.39
Karen	S.T.17	19.00±3.77	211.67±2.08	0.33±0.03	<5	25.4±0.20	6.68±0.34
	A.A.18	29.83±1.18	200.33±3.51	0.30±0.02	<5	28.1±0.10	6.60±0.26
	N.C.19	15.70±0.78	203.67±3.51	0.32±0.00	<5	26.17±0.06	8.27±0.06
	K.C.20	15.56±2.27	298.67±9.45	0.46.023	<5	20.8±0.17	6.73±0.12
City Centre	E.A.21	21.53±0.31	201.00±2.44	1.21±1.55	<5	27.1±0.00	9.33±0.12
	B.H.22	13.43±0.47	215.33±5.69	0.33±0.03	10.0	27.97±0.67	8.14±0.05
	K.H.23	16.23±0.06	210.67±6.66	0.32±0.02	5.0	21.87±2.06	7.70±0.00
	R.P.24	18.00±0.17	198.67±1.53	0.33±0.05	<5	27.2±0.00	8.50±0.40
	M.W.25	19.40±0.20	235.33±6.43	0.36±0.02	<5	20.33±1.20	8.80±0.61
Industrial	K.C.26	7.15±0.15	293.00±6.56	0.45±0.02	<5	24.5±1.41	6.93±0.49
Area	C.B.27	7.00±0.02	335.67±3.06	0.52±0.01	5.0	20.67±0.32	10.27±0.21
	C.B.28	10.10±0.13	337.67±16.74	0.51±0.02	<5	26.20±0.17	9.50±0.17
	A.C.29	0.16±0.02	569.67±2.52	0.92±0.02	<5	26.77±0.32	8.13±0.06
	F.E.30	2.07±0.21	360.33±0.58	0.58±0.01	<5	25.3±0.36	8.37±0.25
WHO Guideline Value		**5.00**	**1200.00**	**-**	**15.0**	**Cool**	**6.5–9.5**
NEMA Standard		**-**	**1200.00**	**-**	**-**	**-**	**6.5-8.5**
KBS Limit		**5.00**	**1500.00**	**-**	**15.0**	**-**	**6.5-8.5**

Table 2: Dry season values (n=30) for physico-chemical parameters at different sampling stations of Nairobi City, Kenya (May-August, 2009)

Zone:	Code	Free Turbidity (N.T.U)	TDS (mg/L)	Conductivity (µS/cm)	Colour (TCU)	Temp. °C	pH (pH Scale)
Kasarani/	H.I.1	0.83±0.06	440.00±8.89	0.67±0.02	<5	26.5±0.35	4.52±0.93
Roysambu	W.C.2	0.89±0.08	597.30±10.79	0.91±0.02	<5	26.5±0.00	4.94±0.24
	K.I.3	2.87±0.30	396.33±4.73	0.60±0.02	<5	26.3±0.06	5.88±1.41
	U.S.4	4.97±0.74	591.67±2.52	0.89±0.02	<5	26.7±0.00	5.63±0.25
	B.C.5	7.70±0.36	155.30±13.28	0.55±0.48	<5	22.4±2.45	7.64±1.63
Dagoretti/	M.D.6	4.90.95	219.33+2.31	0.33±0.02	<5	27.2±1.02	9.92±0.73

Kawangware	D.C.7	4.10±0.00	176.33±3.51	0.28±0.03	<5	27.5±0.23	6.25±0.53
	D.H.8	3.13±0.06	318.3±7.37	0.49±0.03	<5	21.8±0.46	8.37±0.31
	P.B.9	3.10±0.1	170.30±2.31	0.28±0.03	<5	24.6±0.23	5.64±0.13
	M.F.10	2.87±0.58	175.60±1.53	0.25±0.01	<5	25.2±0.00	8.33±1.40
Embakasi	T.S.11	4.40.20	446.67±3.06	0.63±0.02	<5	26.8±0.06	7.73±0.12
	J.A.12	21.47±0.55	877.67±8.62	1.32±0.01	<5	24.5±0.00	6.80±0.00
	J.A.13	20.23±1.21	532.33±11.85	0.80±0.01	<5	24.1±0.06	5.47±o.12
	H.G.14	6.27±0.12	581.33±16.07	0.97±0.17	10.00	23.5±0.75	6.60±0.35
	B.P.15	18.43±0.29	653.00±21.79	1.02±0.04	<5	25.1±1.33	5.40±0.20
Langata/ Karen	S.T.16	13.53±0.40	209.33±6.11	0.39±0.08	<5	21.4±0.20	7.83±0.25
	S.T.17	14.27±2.14	206.33±7.51	0.36±0.05	<5	22.9±0.23	6.90±0.10
	A.A.18	5.40±0.10	206.00±2.65	0.31±0.01	<5	25.7±0.00	10.43±0.41
	N.C.19	7.27±0.21	198.33±1.15	0.30±0.20	<5	19.3±0.20	9.58±0.44
	K.C.20	5.54±0.12	256.67±2.52	0.39±0.02	<5	24.6±0.35	8.98±0.32
City Centre	E.A.21	11.55±0.33	201.00±1.53	0.30±0.01	<5	25.5±0.12	7.70±0.26
	B.H.22	9.83±0.25	225.00±4.36	0.35±0.03	50.00	25.8±0.21	9.37±0.15
	K.H.23	11.03±0.97	193.67±5.13	0.33±0.03	5.00	20.8±0.58	9.13±0.32
	R.P.24	9.70±0.46	189.67±4.93	0.29±0.01	<5	27.1±0.31	9.57±1.42
	M.W.25	21.67±1.03	228.00±10.82	0.44±0.05	<5	21.5±0.00	8.37±0.25
Industrial Area	K.C.26	11.93±1.50	274.00±19.70	0.46±0.03	<5	25.1±0.12	7.47±0.31
	C.B.27	5.67±0.50	296.67±11.06	0.44±0.02	5.00	24.8±0.17	7.60±0.35
	C.B.28	5.94±0.75	338.67±1.15	0.55±0.05	<5	29.1±0.06	9.33±0.42
	A.C.29	10.59±1.49	577.67±4.04	0.87±0.01	<5	27.5±0.12	9.53±0.31
	F.E.30	11.73±0.81	423.67±7.09	0.66±0.04	<5	26.9±0.0	9.37±0.38

					0	
WHO Guideline Value	5.00	1200	-	15.0	Cool	6.5-8.5
NEMA Standard	-	1200	-	-	-	6.5-8.5
KBS Limit	5.00	1500	-	15.0	-	6.5–9.5

3.2 Heavy Metals

The study revealed that Lead values exceed the WHO 2008 guide limit of 0.01 ppm with zone E and F having the highest mean value of 0.28±0.02 ppm during the wet season and zone D and F recording 0.3±0.08 and 0.29±0.03 ppm respectively in the dry season. Highest Cadmium mean value of 0.03±0.01 ppm was recorded in zone B during the dry season. Cadmium levels were below detection limit during the wet season while few traces were detected in zone A (0.023±0.01), B (0.025±0.01) and F (0.008±0.00) ppm.

Table 3: Wet season values (n=30) for all heavy metals at different sampling stations of Nairobi City, Kenya (May- August, 2009). All values are in ppm

	Sample Code	Zn	Cd	Cu	Ni	Cr	Pb	Hg	As
Zone:	H.I.1	0.01±0.01	BDL	BDL	0.03±0.00	BDL	0.13±0.01	0.0016±0.00	0.010
Kasarani/	W.C.2	0.03±0.00	BDL	BDL	0.03±0.00	BDL	0.13±0.00	0.0015±0.00	0.004
Roysambu	K.I.3	BDL	BDL	BDL	0.04±0.01	BDL	0.20±0.00	0.0021±0.00	BDL
	U.S.4	BDL	BDL	BDL	0.05±0.00	BDL	0.16±0.00	0.0016±0.00	0.006
	B.C.5	1.09±0.01	BDL	BDL	0.05±0.00	BDL	0.21±0.00	0.0017±0.00	0.005
	M.D.6	BDL	BDL	BDL	0.05±0.00	BDL	0.10±0.00	0.0014±0.00	BDL
Dagoretti/	D.C.7	BDL	BDL	BDL	0.04±0.00	BDL	0.15±0.01	0.0014±0.00	BDL
Kawangware	D.H.8	BDL	BDL	BDL	0.06±0.00	BDL	0.18±0.00	0.0017±0.00	BDL
	P.B.9	BDL	BDL	BDL	0.03±0.00	BDL	0.23±0.00	0.0016±0.00	BDL
	M.F.10	0.39±0.00	BDL	BDL	0.04±0.00	BDL	0.30±0.00	0.0027±0.00	BDL
	T.S.11	0.08±0.00	BDL	BDL	0.04±0.00	BDL	0.19±0.00	0.0019±0.00	BDL
Embakasi	J.A.12	BDL	BDL	BDL	0.03±0.00	BDL	0.24±0.00	0.0019±0.00	0.008
	J.A.13	0.62±0.01	BDL	BDL	0.03±0.00	BDL	0.20±0.00	0.0016±0.00	0.017
	H.G.14	0.07±0.00	BDL	BDL	0.03±0.01	BDL	0.16±0.00	0.0018±0.00	BDL
	B.P.15	BDL	BDL	BDL	0.03±0.00	BDL	0.25±0.00	0.0017±0.00	BDL
	S.T.16	0.28±0.00	BDL	BDL	0.02±0.00	BDL	0.21±0.00	0.0017±0.00	BDL
Langata/	S.T.17	BDL	BDL	BDL	0.03±0.00	BDL	0.25±0.00	0.0016±0.00	BDL
Karen	A.A.18	0.04±0.00	BDL	BDL	0.03±0.00	BDL	0.27±0.00	0.0018±0.00	0.007
	N.C.19	0.02±0.01	BDL	BDL	0.02±0.00	BDL	0.26±0.00	0.0019±0.00	BDL
	K.C.20	BDL	BDL	BDL	0.02±0.00	BDL	0.29±0.00	0.0017±0.00	BDL
	E.A.21	0.03±0.00	BDL	BDL	0.04±0.00	BDL	0.25±0.00	0.0018±0.00	0.029
City Centre	B.H.22	BDL	BDL	BDL	0.03±0.00	BDL	0.28±0.00	0.0016±0.00	0.005
	K.H.23	0.18±0.01	BDL	BDL	0.03±0.00	BDL	0.29±0.00	0.0010±0.00	BDL
	R.P.24	BDL	BDL	BDL	0.03±0.00	BDL	0.29±0.00	0.0006±0.00	0.013

	M.W.25	BDL	BDL	BDL	0.04±0.00	BDL	0.29±0.00	0.0006±0.00	0.019
Industrial Area	K.C.26	BDL	BDL	BDL	0.04±0.00	BDL	0.31±0.00	0.0005±0.00	0.012
	C.B.27	BDL	BDL	BDL	0.05±0.00	BDL	0.33±0.00	0.0019±0.00	BDL
	C.B.28	BDL	BDL	BDL	0.04±0.00	BDL	0.33±0.01	0.0021±0.00	0.008
	A.C.29	0.05±0.01	BDL	8.18	0.05±0.00	BDL	0.22±0.00	0.0036±0.00	BDL
	F.E.30	0.03±0.00	BDL	4.80	0.03±0.01	BDL	0.19±0.00	0.0034±0.00	BDL
WHO Guideline Value		3.00	0.003	2.00	0.07	0.05	0.01	0.006	0.01
NEMA Standard		1.50	0.01	0.05	-	-	0.05	-	0.01
KBS Limit -		5.00	0.005	0.10	-	0.05	0.05	0.001	0.05
Limit of detection		0.01	0.001	0.02	0.007	0.005	0.001	0.0001	0.002

BDL: Below Detection Limit

Table 4: Dry season values (n=30) for all heavy metals at different sampling stations of Nairobi City, Kenya (May- August, 2009). All values are in ppm

	Sample Code	Zn	Cd	Cu	Ni	Cr	Pb	Hg	As
Zone: Kasarani/ Roysambu	H.I.1	0.22±0.00	0.02±0.00	BDL	0.12±0.02	0.37±0.01	0.06±0.01	0.0018±0.00	BDL
	W.C.2	0.05±0.00	0.02±0.01	BDL	0.35±0.06	0.36±0.01	0.10±0.01	0.0020±0.00	0.005
	K.I.3	0.42±0.00	0.02±0.00	BDL	0.41±0.04	0.37±0.02	0.19±0.01	0.0021±0.00	0.004
	U.S.4	BDL	0.03±0.01	BDL	0.51±0.03	0.44±0.00	0.10±0.02	0.0017±0.00	0.003
	B.C.5	0.12±0.00	0.03±0.01	BDL	0.50±0.03	0.44±0.00	0.10±0.01	0.0021±0.00	BDL
Dagoretti/ Kawangware	M.D.6	BDL	0.03±0.00	BDL	0.43±0.04	0.46±0.01	0.12±0.02	0.0019±0.00	0.005
	D.C.7	BDL	0.03±0.00	BDL	0.20±0.00	0.49±0.01	0.12±0.01	0.0013±0.00	0.005
	D.H.8	0.04±0.00	0.03±0.00	BDL	0.23±0.02	0.50±0.01	0.15±0.01	0.0024±0.00	BDL
	P.B.9	BDL	0.04±0.01	BDL	0.23±0.01	0.51±0.01	0.11±0.01	0.0018±0.00	0.005
	M.F.10	BDL	BDL	BDL	0.21±0.02	0.51±0.01	0.15±0.02	0.0031±0.00	BDL
Embakasi	T.S.11	0.06±0.00	BDL	BDL	0.23±0.01	0.52±0.01	0.17±0.01	0.0019±0.00	BDL
	J.A.12	BDL	BDL	BDL	0.21±0.01	BDL	0.17±0.01	0.0018±0.00	0.010
	J.A.13	0.58±0.00	BDL	BDL	0.18±0.01	BDL	0.32±0.32	0.0016±0.00	0.015
	H.G.14	0.4±0.00	BDL	BDL	0.19±0.01	BDL	0.23±0.01	0.0018±0.00	BDL
	B.P.15	0.14±0.00	BDL	BDL	0.20±0.01	BDL	0.21±0.01	0.0019±0.00	BDL
Langata/ Karen	S.T.16	0.16±0.00	BDL	BDL	0.24±0.02	BDL	0.22±0.01	0.0017±0.00	0.013
	S.T.17	0.73±0.00	BDL	BDL	0.22±0.01	BDL	0.33±0.01	0.0017±0.00	0.006
	A.A.18	0.19±0.00	BDL	BDL	0.23±0.02	BDL	0.22±0.01	0.0020±0.00	0.008
	N.C.19	0.32±0.00	BDL	BDL	0.24±0.01	BDL	0.30±0.04	0.0018±0.00	0.008
	K.C.20	0.51±0.02	BDL	BDL	0.22±0.01	BDL	0.42±0.01	0.0019±0.00	BDL
City Centre	E.A.21	0.21±0.00	BDL	BDL	0.24±0.01	BDL	0.24±0.02	0.0017±0.00	BDL
	B.H.22	0.11±0.00	BDL	BDL	0.23±0.02	BDL	0.22±0.01	0.0016±0.00	0.007
	K.H.23	0.68±0.00	BDL	BDL	0.25±0.01	BDL	0.27±0.02	0.0013±0.00	BDL

	R.P.24	0.14±0.00	BDL	BDL	0.26±0.01	BDL	0.24±0.02	0.0010±0.00	0.014
	M.W.25	0.12±0.00	BDL	BDL	0.30±0.03	BDL	0.25±0.01	0.0007±0.00	0.019
	K.C.26	0.25±0.00	BDL	BDL	0.33±0.02	0.01±0.01	0.26±0.00	0.0010±0.00	0.003
Industrial	C.B.27	0.33±0.00	0.01±0.00	BDL	0.22±0.01	BDL	0.33±0.03	0.0019±0.00	0.013
Area	C.B.28	0.13±0.00	0.01±0.00	BDL	0.26±0.02	0.01±0.01	0.26±0.03	0.0024±0.00	0.007
	A.C.29	0.08±0.00	0.01±0.00	BDL	0.21±0.01	0.10±0.01	0.28±0.02	0.0034±0.00	0.004
	F.E.30	0.19±0.00	0.01±0.00	BDL	0.22±0.02	0.11±0.02	0.31±0.01	0.0037±0.00	0.009
WHO Guideline Value		3.00	0.003	2.00	0.07	0.05	0.01	0.006	0.01
NEMA Standard		1.50	0.01	0.05	-	-	0.05	-	0.01
KBS Limit	-	5.00	0.01	0.10	-	0.05	0.05	0.001	0.05
Limit of detection		0.01	0.001	0.02	0.007	0.005	0.001	0.0001	0.002

4.0 Discussion

The groundwater quality showed a significant variation between the wet and the dry seasons. Most of the parameters measured gave an indication of higher concentrations during the dry season that during the wet season. The temperature for the two seasons stood between 20^{o}C and 31^{o}C with the wet season being warmer. Colour was generally invariable except for two boreholes (H.G.14 and B.H.22) which recorded a deteriorating colour change.

In general, water with a low pH (< 6.5) could be acidic and corrosive and therefore, the water could contain metal ions or, on other words, elevated levels of toxic metals. Kasarani area recorded elevated levels of Cd with Ni and Cr ions recording the highest. These were also indicated by high levels of TDS. The plate on the left shows one of the places witnessed during sampling where corrosion of pipes was evident.

Figure 2: Corrosion of pipes in HACO Industries, Kasarani

Groundwater in Nairobi was very turbid above the guidelines. Karen/Langata area was the most turbid area with borehole A.A.18 recording the highest reading. The borehole is located in Langata inside a two acre vegetable farm with very fine loamy soil structure. The suspended particles also can be thought to help the attachment of heavy metals especially lead which has manifested to be high. Most of the organizations where sampling was done use borehole water for processing, manufacturing, drinking or bottling purposes.

Borehole J.A.12 in Jomo Kenyatta Airport (Embakasi area) had the highest level of both TDS and Conductivity during the two seasons though the levels were within WHO (2008) and NEMA guidelines. The high levels of TDS in this borehole are also related to high salinity levels recorded. Embakasi area revealed to be area with higher TDS and conductivity. The borehole is in confined aquifer and the most

probable source of high TDS and conductivity could be from the presence of other ions e.g chlorides. High abstraction rates could as well lead to increase in dissolved ions in groundwater.

The study revealed that the dry season had elevated concentrations of heavy metals compared to the wet season. Concentrations varied from one zone to another and in some instances, boreholes within the same zone featured different characteristics.

Though WHO (2008) guidelines have not provided for a limit, Zn in the study area was low and within the National Environment Management Authority (NEMA) standard of 1.5 ppm. The mean concentration for the region was 0.1±0.2 and 0.21±0.2 during the wet and the dry season, and likely reflects the natural low background concentrations. During the wet season, Cd was below the detection limit. Levels far above WHO standards of 0.003 ppm were detected in Kasarani/Roysambu area, Dagoretti/Kawangware area and Industrial area during the dry season. Cd in Nairobi can be concluded to be controlled by geology rather than anthropogenic pollutants input (Olago and Akech, 2001). Cu was below detection limit in both seasons except for two boreholes in Industrial area; A.C.29 and F.E.30 which showed elevated concentrations above 2 mg/L in during the wet season. Cu below detection limit justifies that the fact that copper strongly attaches to organic matter and minerals and it hardly ever enters groundwater. The two boreholes mentioned above can be considered as an abnormally occurrence. Location of the two boreholes in the industrial setting could be the most probable source of detected Cu concentrations. The other possible source would be contact with copper plumbing and copper-containing fixtures in the water distribution system.

All boreholes showed low Ni concentrations during the wet season but detected high concentrations far above the recommended WHO guideline value of 0.07 ppm during the dry season. Except for Kasarani/Roysambu area that recorded the highest Ni mean of 0.38 ppm, other sub-regions had a mean close to 0.24 ppm. These concentrations are primarily controlled by geology (Olago and Akech, 2001). Another possible source of Nickel detected may be direct recharge and since Nickel is one of the most mobile of the heavy metals in the aquatic environment, it could have found its way easily to the aquifers and spread to groundwater.

The area of study revealed high concentrations of Pb above the WHO (2008) guidelines. The highest concentration was detected in Karen and this could be attributed to high Pb background levels in soils as well as seepage of chemicals from flower farms in the locality. Other areas which recorded high levels were the City centre and Industrial area. In Industrial area, widespread use of leaded products is expected in ceramic industries, glass industries, Polyvinyl Chloride (PVC) plastics and lead acid batteries production plants. Improper disposal of these used lead products could easily have contaminated the soil hence finding its way into the groundwater. Before the introduction of unleaded fuel in the country, there is a possibility of leaded fuel spillage into the soil, and surface runoff infiltration into the ground through rock fractures especially in the City centre where high traffic is prevalent.

Chromium levels were below the detection limit during the wet season for the entire region. All boreholes in Kasarani/Roysambu and Dagoretti sub-regions showed high concentrations during the dry season that exceed permissible WHO/Kenya Bureau of Standards (KEBS) guidelines. Only one borehole (T.S.11) in Embakasi sub-region showed high levels of Cr. Borehole T.S.11 happened to have highest concentrations detected. This could be attributed to high geological background levels since the area has a confined aquifer rather than anthropogenic pollutants input.

Kasarani/Roysambu and Dagoretti areas have few industries undertaking such works as making tents, beauty products and concrete works. In addition to sources from direct recharge and natural backgrounds, such activities could also contribute to the high Cr levels detected in those sub-regions. Traces of mercury detected were below the WHO guideline value of 0.006 ppm. The traces may not have their origin as Nairobi area but the source may be traced back from recharge areas where common wastes such as batteries and fluorescent tubes are carelessly disposed. This relates to concentrations of Hg greater than 0.001 ppm in Ngong rivers reported by Kithia (1992), this being a groundwater recharge zone. Mean arsenic level in both seasons was low in all regions except for the City centre zone that recorded a mean of 0.013. Borehole E.A.21 in the City centre zone showed elevated level of 0.029 during the dry season. However, arsenic was below for the same borehole was below detection limit during the dry season. Boreholes where arsenic level was above WHO drinking water standards in both seasons were J.A.13, R.P.24 and M.W.25. The traces detected can be concluded to have originated from direct recharge and not necessarily natural background from rocks.

5.0 Conclusion and Recommendations

The variations of physical and chemical parameters observed in Nairobi groundwater was determined by some controlling factors. Those factors are hydrological regime of groundwater at different times of the year which cause changes in water rest levels, precipitation chemistry (rainfall) which contributes to recharge of groundwater and bedrock chemistry which influences inputs of dissolved ions into the aquifers. Anthropogenic sources like poor waste management practices contribute negatively by adding pollutants which find their way to the groundwater through recharge zones and seepage.

The increase in concentration levels during the dry season could be attributed to seepage after the wet season. Most of the ions analysed are soluble in water and would dissolve into the soils once it rains. Dissolved ions take time to seep into the aquifer after infiltration during the wet season. Pollutants that find their way into the aquifer through direct recharge also take time to flow with groundwater hence higher levels during the dry season.

It is therefore recommended that there should be periodic evaluation of groundwater quality in the area since groundwater is a major source of domestic / commercial water supply, which will likely expose the large population of the area to health hazards due to long-term and cumulative effects these ions might have.

The results suggest that groundwater from Nairobi boreholes need to be treated so that the water could meet WHO drinking water standards. Plain sedimentation or use of cloth/membrane filters may be used remove turbidity while reverse osmosis could be one of the appropriate methods for water treatment that could be used where heavy metals are present.

There is need to establish an efficient periodic monitoring system to evaluate levels of heavy metals in groundwater as well as surveillance of heavy metals levels in bottled water abstracted from the ground. Population growth has been cited in this research as being a key driving force for deteriorating groundwater quality. Due to pressure for more land for housing and other developments, there is need to start aggressive campaign geared towards decongesting the city and reducing the rate of population growth. This can be achieved through government policies, funding institution and private enterprises.

It is important that groundwater resources in Nairobi area be guarded against pollution and other degrading activities in order to contribute to better sustainability of the environment and the future of mankind.

References

APHA (American Public Health Association) (1995). Standard Methods for Examination of Water and Wastewater. 15th Ed., Washington DC., USA.

Appelo, C. A. J. and Postma, D. (1996). Geochemistry, groundwater and pollution. 3rd Edition, pp 11 – 12.

Central Bureau of Statistics, (2010). Population and Housing Census, Republic of Kenya.

Cronin, A. A., Taylor, R. G., Powell K. L., Barrett, M. H., Trowsdale, S. A. and Lerner, D. N. (2003). Temporal trends in the hydrochemistry and sewage-related microbiology of an urban sandstone aquifer – Nottingham. United Kingdom. *Hydrogeology Journal,* Vol. **11**(2). pp 205-216.

Fairburn, W. A., (1963). Geology of the North Machakos-Thika Area. Rep. No. 59, Surv. Kenya.

Freeze, R. A. and Cherry, J. A. (1979). Groundwater. Prentice Hall Inc., New Jersey.

Gevaerts, E. A. L. (1964). Hydrogeology of the Nairobi Area. Technical report NO. 1, Ministry of Natural Resources and Wild Life, Water Development Dept. **1**, pp 13 – 34.

Kithia, S. M., (1992). Effects of Industries and other Land Use Systems on the Water Quality Within the Nairobi Rivers Sub-catchments, Kenya. M.Sc. Thesis, University of Nairobi.

Larsson, I. (1984). Groundwater in Hard Rocks: A contribution to the International Hydrological Programme. Studies and Reports in Hydrology No. 33. UNESCO. Paris, France.

Michael, P. (1994). Introducing groundwater. 4th Edition, pg 37 – 63, 163 – 164, 183-184.

Olago, D. O. and Akech, N. O., (2001). Pollution Assessment in Nairobi River Basin. In P.F.Okoth and P. Otieno (eds). Pollution Assessment Report of The Nairobi River Basin Project. UNEP/Africa Water Network.

Raghunath, H. M. (1987). Groundwater. 2nd Edition, pp 457 – 459.

Saggerson, E. P. (1991). Geology of Nairobi Area. Report No. 98. Mines and Geological Department, Nairobi.

Sinclair, I. C. (2000). 'Better Laws = Better Environment: The Role of the Environmental Lawyer in the Reconstruction and Modernization of the Water Sector in the Private Sector Participation', *Water, Air and Soil Pollution,* Vol. **123**, pp 353-360.

Talukder, S. A., Chatterjee, A., Zheng, J. and Kosmus, W. (1998). Studies of Drinking Water Quality and Arsenic Calamity in Groundwater of Bangladesh. Proceedings of the International Conference on Arsenic Pollution of Groundwater in Bangladesh: Causes, Effects and Remedies, Dhaka, Bangladesh, February 1998.

WHO, (2008). Guidelines for drinking-water quality, 3rd ed. Vol. 1. Geneva, World Health Organization.

YOUTH LED MSEs INVESTMENT IN TECHNOLOGY: AIDING BUSINESS GROWTH OR A NOUGHT?

E. W. Gakure and P. P. Kithae
Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
Kenya Institute of Management, Makueni, Kenya
E-mail pkithae2001@yahoo.com

Abstract
Technology has been described as "the systematic application of scientific and other organized knowledge to practical task". When applied to micro and small enterprises, technology has proved to be the engine of economic growth amongst "Asian Tigers". The purpose of technology is to improve productivity of enterprises, and enhance the quality of goods produced by enterprises to help them withstand local and international competition. According to Haan (1999), there is evidence that SMEs in Kenya are continually engaged in adapting Industrial equipment for their own use and self constructing tools and equipment. There is also evidence that other informal sources of information such as friends and simple imitation through observations are common. Coupled with this, the Kenyan government has done a lot in creating enabling environment for youth led MSES to compete favourably with other enterprises Youths are innovative, enthusiastic, vibrant and optimistic. Given a chance, youths are capable of transferring their acquired technologies into business enterprises and drive Kenya towards achieving its vision 2030. However, most youths are not employed. They are not starting own enterprises to create jobs for themselves and for others. Even their already started MSES are closing up within their first two years after start up. The baseline survey of 1999 estimated that 80% of the MSEs fail within their first three years due to problems related to appropriate technology. This research study aimed at investigating how technologies that youth acquired in various forums and learning institutions affect performance of their enterprises. It used training, purchase of equipment, franchising and sub-contracting (forms of technology) as its independent variables while Improved product quality, increased efficiency, increased output, increased sales, improved sustainability and increased profits and market share (effects on MSE performance) were its dependent variable. Both qualitative and quantitative research designs were used. Quantitative design revealed the direction and strengths of the variables while qualitative design discussed the main themes. The design was descriptive in nature; as Gall and Borg (1989) noted, "Descriptive studies by nature emphasis interpretation". The target population for the study was youth led MSEs in Makueni district who received any form of technology between 2000 and 2007. The total number of all MSES in the district was estimated at 1320. Assuming those led by youths were 30 % (as youths are 30% of total house holds (GOK, 2006)), our target population became 396. The findings of the study were summed up in form of an MSE technology adoption model which showed that dependent variables were a function of investment in technology. Consequently, these variables affect performance of MSE which in turn influences the type of investment in technology that the MSE adopts. At start-ups and early stages of business growth, there is very minimal investment in technology which results to inappropriate technology adoption forms and consequently to ineffective MSE performance. The study recommended a deliberate action to be taken in form of refresher courses for entrepreneurs and more capital injection to finance all the four forms of investments in technology and assist the MSES to break the vicious circle of poor performance. Once this is done, it was projected that the resulting technology will be able to help youth led MSES to achieve improvement of product and service quality, increased efficiency, increased output and sales volume, and increased profitability and market share. These profits would then be re-invested in technology to further enhance the enterprises' sustainability and global competitiveness and thus empower youth to build a better Kenya.

1.0 Introduction

1.1 Background of the Study

Technology has been described as "the systematic application of scientific and other organized knowledge to practical task" (Galbraith, 1971). When applied to micro and small enterprises, technology has proved to be the engine of economic growth amongst "Asian Tigers". The foregoing is a research project conducted in Makueni district and whose aim was to investigate how technologies that youth acquired in various forums and learning institutions affect performance of their enterprises. Technology has been identified as an enabler of economic growth as well as a means through which SMEs can gain competitiveness through creativity and innovativeness.

1.1.1 Micro and Small Enterprises (MSES)

The economic recovery strategy for wealth and employment creation recognizes the great role that MSE sector play in wealth generation, employment creation and poverty reduction (GOK, 2003). The strategy paper goes on to state that the sector contributes about 18% GDP and plays a critical role in easing foreign exchange constraint, in penetrating new markets and in stimulating growth and development particularly in the rural areas. The sector also acts as the seed bed for entrepreneurial pursuits and complements the process of adjustment in large enterprises by bringing backward and forward linkages for products and services previously not available in the market.

The purpose of technology is to improve productivity of enterprises, and enhance the quality of goods produced by enterprises to help them with-stand local and international competition (ILO/UNDP, 2000).In a market – oriented environment, one way of achieving and maintaining competitiveness is by creating knowledge faster than competitors (Albu , 1997: Maskell and Malmberg, 1999). In turn, this depends on cost advantages, innovation and the continuous improvement of products and services – all coming through the capability to generate and manage technical change (Moyi and Njiraini. 2005).

In Kenya, MSEs have restricted levels of technology, in appropriate technology and inadequate institutional capacity to support adaptation and absorption of modern technological skills. Such enterprises suffer from lack of information on existing technologies and are exposed to a weak environment that hampers coordination and transfer of technology. They have no way of gauging appropriateness of technology. In addition, there is a wide gap between the suppliers of technology and the end users of technology products."(GOK, 2003). Effective transfer of technology is therefore not taking place in the country because decisions relating to cost aspects rest with multinational corporations" (GOK, 1982).

1.2 Statement of the Problem

Kenyan Youth has been defined as one aged between fifteen and thirty years (GOK, 2006). According to the Ministry of state for youth affairs draft strategic plan of March 2006, the youth in Kenya number about 9.1 million and account for about 32% of the population.

They form 60% of the total labour force but many of them have not been absorbed in the job market owing to the country's high unemployment level (GOK, 2006). Youths are innovative, enthusiastic, vibrant and optimistic. Given a chance, youths are capable of transferring their acquired technologies into business enterprises and drive Kenya towards achieving its vision 2030 (GOK, 2007). However things are different. Most youths are not employed (GOK, 2006). They are not starting own enterprises to create jobs for themselves and for others. Even the already started MSES are closing up within their first two years after start up (Nelson, 1986).

The purpose of technology is to improve productivity of enterprises, and enhance the quality of goods produced by enterprises to help them with-stand local and international competition (ILO/UNDP, 2000). Technology transfer can be defined as the process that allows techniques, knowledge as well as products and management practices to flow from one entity to another (Moyi and Njiraini, 2005). Formal means of technology transfer include acquisition of capital equipments and machinery through trade, licensing and/ or franchising agreements. According to Haan (1999), there is evidence that SMEs in Kenya are continually engaged in adapting Industrial equipment for their own use and self constructing tools and equipment. There is also evidence that other informal sources of information such as friends and simple imitation through observations are common (Ngahu, 1995; Haan, 1999). Coupled with this, the government of Kenya has done the following to empower the youth. First, the government has issued new regulations on tendering so that all government agencies will be compelled to give preferential treatment to bids for MSES. Specifically, all district tender boards should give at least 10% of their tenders to youth owned MSES in the district (GOK, 2007).

Secondly, the government has encouraged technical Institutes and other relevant bodies to develop simple goods and production methods. Thirdly, the government has been disseminating information on new products and production methods to potential producers. Fourthly, the government has revised building codes to favour architectural and engineering structures that make intensive use of products supplied by MSEs; and, lastly, the government has encouraged the formation of co-operatives as a means through which MSEs would access information and support on technology, credit, input and markets (Moya and Njiraini, 2005).

However, despite all this, the baseline survey of 1999 estimated that 80% of the MSEs fail within their first three years due to problems related to appropriate technology (GOK, 2001). This research study aimed at finding reasons for this so as to bridge the existing gap. It was to reveal technology adoption forms applied and their effect on performance of youth led MSEs. Specifically, the study was to investigate if there is any relationship between technologies that youth acquired in various forums and learning institutions and performance of their enterprises. Once completed, the study aimed at empowering youth to build a better Kenya.

1.3 General Objective

The over all objective of this study was to find out if there is any relationship between technologies that youth acquired and performance of their enterprises.

1.4 Specific Objectives

Specific objectives were as follows:

1. To investigate whether technology affects quality of youth led MSE's products and services.
2. To determine if technology influences acquisition of financial resources in youth led MSEs.
3. To find out whether technology affects productivity of youth led MSEs.
4. To determine if technology affects sustainability of youth led MSEs.
5. To investigate if technology influences marketability of youth led MSE's products and services

1.5 Research questions

The following are research questions that this study aimed to answer.

1. Does technology affect quality of youth led MSE's products and services?
2. Does technology influence acquisition of financial resources in youth led MSEs?
3. Does technology affect productivity of youth led MSEs?
4. Does technology affect sustainability of youth led MSEs?

5. Does technology influence marketability of youth led MSE's products and services?

1.6 Significance of the study

To donor agencies

The findings will be of great assistance to donors as they will be able to engage suitable technology transfer mechanisms and implementers. It will also give direction on prioritizing the expenditure of the donors and policy makers in consideration to areas where the strategies should be focused so as to effectively promote youth led MSEs development

To the government

The findings will be of great assistance to the government in its policy making process as it will improve those inhibitors to technology successes.

1.7 Assumptions of the study

The study assumed that technology has not brought much impact on the target beneficiaries and that something need be done to improve its successes. It was further assumed that the respondents to the interview would provide sincere and honest information and views. The study further assumed that the number of entrepreneurs interviewed would be fair representation of all entrepreneurs who received technology within the years under consideration.

1.8 Definition of terms

This section deals with operational definitions whose role is to indicate the specific manner in which a term or concept is to be applied. Their use may be different in another perspective. This study used the following concepts.

1.9 Micro and small enterprises (MSEs)

A micro or small enterprise is an undertaking, which employs between 1 and 20 employees, with capital investment of not more than kshs 30 million. Operational and administrative management lies in the hands of one to three persons who usually make major decisions.

1.10 Technology

According to Van Dijk (2001), Technology may be seen as a resource that can be useful if adapted by firms to improve their efficiency and factor productivity. This study used the same definition.

1.11 Technology adoption

Is the modification of an existing technology to meet the needs of specific types of producers or consumers, become compatible with locally available materials or local tastes and preferences or take advantage of a relative abundance of labour relative to capital (Van Dijk, 2001).

1.12 The youth

A Kenyan Youth has been defined as one aged between 15 – 30 years. The youth in Kenya, who number about 9.1 million, account for about 32% of the population.

2.0 Literature Review

2.1 Conceptual Frame Work

Conceptual frame work shows effect of Independent variables (forms of technology) on dependent variable (Performance of youth led MSE). If conditions are favorable, it is expected that youths will adopt their acquired technology to improve productivity of their MSEs, enhance quality of goods produced to help their enterprises with-stand local and international competition (ILO/UNDP, 2000).

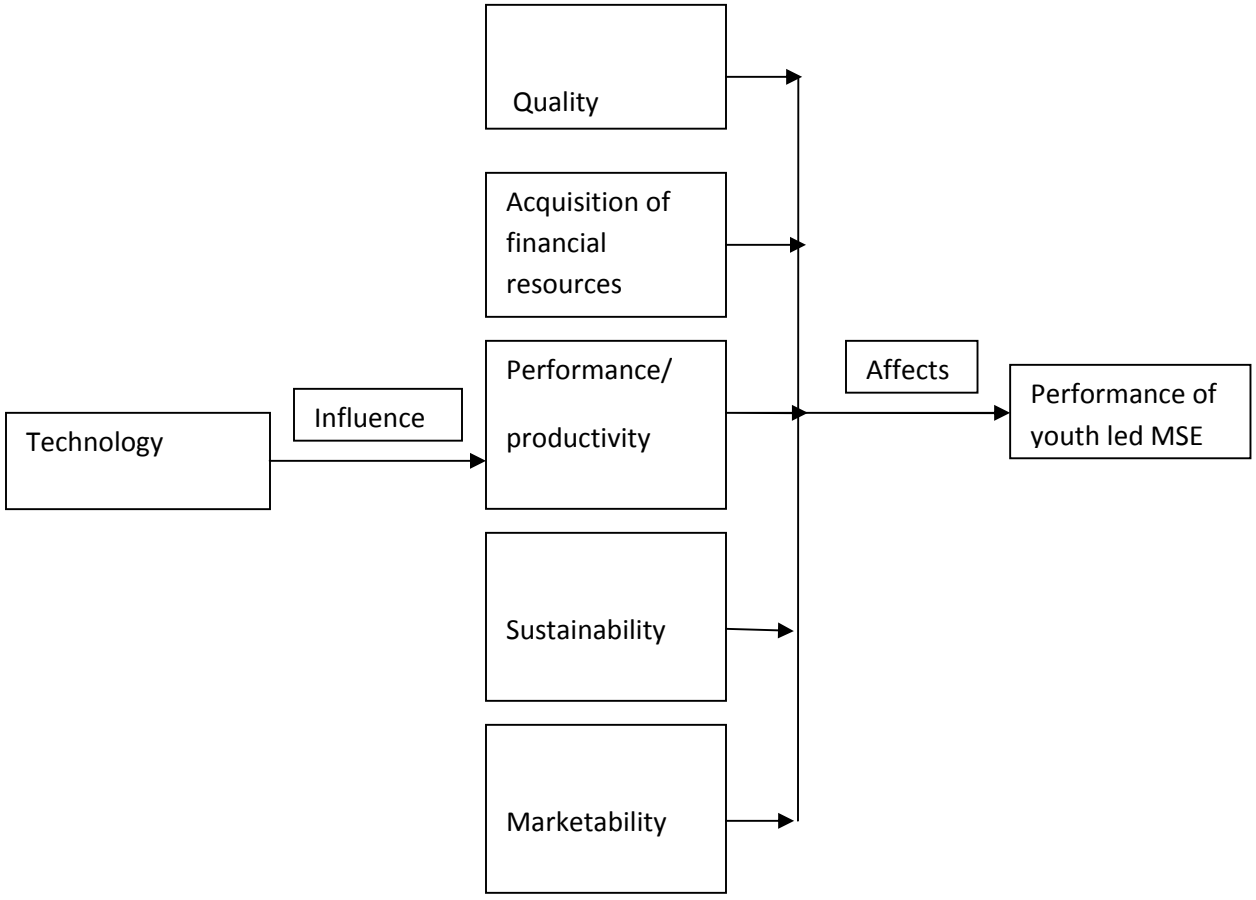


Figure 1: Conceptual framework

The diagram above illustrates the relationship between forms of technology adoption and performance of MSEs (the dependent variable). The study conceptualized that technology adoption would form independent variables and their effects was expected to impact positively on the performance of MSEs. These are explained as follows.

2.1.2 Performance of Youth led MSE

This time round, most firms have to rise up to the challenge of operating in a very dynamic, technological, competitive and volatile environment. It is only those firms that will embrace quality as their core business which will survive the onslaught that competition brings with it.

There are many new market entrants with 'bigger stick' which will give existing firms a good run for their money. Successful business operation depends on the ability to complete; the ability to compete depends largely on the quality of the product (Lyman & Grubellini, 1975). This will, therefore require that an entrepreneurial organization works towards product/service improvement on a continuous basis. This will, in turn, call for managerial talent that is capable of harnessing organizational resources – human, material, physical and informational resources- efficiently and effectively toward meeting the organizations objectives and goals. Most organizations objectives are to make profit; which is partly realized through the provision of competitive and quality products/services.

There is a growing realization that high quality goods and services can give an organization a considerable competitive edge. Good quality reduces the cost of rework, scrap, and returns and, most importantly, generates satisfied customers. The entrepreneur may opt to employ a flat organizational structure with informal networks throughout (Hisrich, 2005) to facilitate an effective control system.

2.1.3 Technology

The purpose of technology is to improve productivity of enterprises, and enhance the quality of goods produced by enterprises to help them with-stand local and international competition (ILO/UNDP, 2000). Studies undertaken in African countries reveal that Africa exhibits much more inter firm technological heterogeneity than other developing regions (Biggs, Shah and Srivastova, 1995). They also reveal a weak learning environment which is attributed to lack of import and export competition. Biggs et al (1995) suggests that the most important investment in new technology that MSEs in Africa can adopt is importation of new technology in form of franchising, sub contracting and licensing.

Technology Transfer

Skills training are a major non-financial promotion programmes which seems quite effective in promoting success to small enterprises. The Kenya Government has seen it so and therefore highlighted it in most of its policy documents. Implementers of the programes are Non-Government Organizations, private Consultants, and Banks, Government Institutions like Kenya Industrial Estates and Ministry of Research Technical Training and Technology among others.

Strategies for enhancing MSES Technology adoption in Kenya

The Kenya Government since its inception has developed strategies and promotion programmes aimed at improving the economy by promoting small and medium enterprises. These programmes are either financial or non-financial. However, the most important of all these is the skills training as it is through personal development that an enterprise culture can be created (ILO/UNDP, 1990; Harper, 1983; Nelson, 1986). Among key priorities in the Embu district development plan for the period 2002-2008 is enhancement of skills and entrepreneurship training through sensitization of indigenous entrepreneurs in processing, management and marketing (GOK, 2001).

To counteract the many challenges posed by globalization, increasing competition, shifting patterns of legislation and regulations, tumbling trade barriers and fragmentation of markets, UNIDO (2004) suggests that MSEs must be internally and internationally competitive to survive and grow. One way of achieving and maintaining competitiveness in a market oriented environment is to be able to create,

distribute and exploit knowledge faster than competitors. In turn, this depends on cost advantages, innovation and the continuous improvement of products and services (Albu, 1997; Maskell and Malmberg, 1999).

It has been observed that about 50% of businesses fail during their first two years of the start-up stage. To arrest the high failure rate, Nelson, (1986) propagated that specific training is needed to assist entrepreneurs go beyond this critical phase. A survey carried out by the Ministry of Commerce and Industry in 1985 on skills development through the Kenya Industrial Estates showed that out of 20 trainees given management and technical training skills with an aim of helping them succeed in their enterprises, only two were considered to be successful in terms of employment creation, increase in assets and increase in profits.

Youth Enterprise Development Fund

The fund was conceived by the Government in June 2006 as a strategic move towards arresting unemployment which is virtually a youth problem (GOK, 2006). According to the Ministry of Youth Affairs circular (2007), the fund has the following objectives:

(i) To provide loans to existing Micro-finance Institutions (MFIs), registered non-governmental organizations (NGOs) involved in Micro-financing, and savings and credit co-operative organizations (SACCOS) for tending to youth enterprises.

(ii) To attract and facilitate investment in micro-small and medium enterprises oriented commercial infrastructure such as business or industrial parks, markets or business incubators that will be beneficial to youth enterprises.

(iii) Support youth oriented micro, small and medium enterprises to develop linkages with large enterprises.

(iv) Facilitate marketing of products and services of youth enterprises in both domestic and international markets; and

(v) Facilitate employment of youth in the international labour market. (GOK, 2006).

While allocating the youth fund, the government recognized the fact that skills acquisition is necessary but not sufficient to improve MSES' performance through technology adoption. Youth enterprise development fund has been in operation for two years and this research aims at discovering how effective it has been in improving performance of the youth led enterprises.

2.1.4 Sustainability

For a competitive MSE to thrive, an enabling legal environment is imperative. Despite a significant achievement in legal reforms within the government sector; a number of existing laws and regulations still remain cumbersome. They include the following: -

a) By laws applied by many local authorities are not standardized and appear, in most cases punitive to technological adoption by youth led MSES.

b) A lot of Bureaucratic and lengthy process of transacting business with government agencies adversely impacts on the operations of the MSES.

c) The single business permit (SBP) system launched in 1999 is not yet operational and the fees are too prohibitive.

d) Centralization of business names registration in Nairobi poses problems for MSES located in rural areas.

e) Similarly, requirements for MSES to give their physical address poses a serious problem to those without permanent physical location. All these results to high costs; forcing many entrepreneurs to stay without registration.

Most MSES consistently encounter harassment from local authorities and Government Officers over attempts to operate on un- used lands, and the daily license fees are normally to exorbitant for the MSES to afford. When there is court dispute, the judicial system is normally complex, expensive and time consuming and sometimes unfair. It also makes sub-contracting, franchising and other business arrangements impossible amongst SMSES. Finally majority of MSES have no legal title deeds for the site or which they operate and they can therefore not invest in their work sites. Absence of security tenure denies them access to credit. Policies regulating the provision of power, roads and water, coupled with difficult building standards compound their insecurity.

2.1.5 Marketability

According to sessional paper No. 2 of 2005 on Development of MSE for wealth and employment creation for poverty reduction; MSEs have inadequate access to physical infrastructure (GOK, 2005). Among the constraining factors is Land tenure in Kenya which is so unfavorable to upcoming MSEs (GOK, 2005).

The Kenya's economic Recovery Strategy paper of 2003 identifies poor infrastructure as a critical factor that constrains profitable business in Kenya (GOK, 2003). The poor state of the country's road network, lack of electricity in rural areas and other ingredients of physical infrastructure all contribute towards unfavorable business environment (Deakins et al, 2003).

Poor state of country's road network, for example, adds cost of producing and marketing of goods and services, thereby rendering the MSEs goods and services less competitive than imported substitutes. Other infrastructural problems include inaccessibility to land, electricity and other utilities.

Land

Most of land related problems of MSEs revolves around ownership title deeds and invasions by private developers (GOK, 2005). Lack of suitable land allocated to MSEs is a major drawback to their growth and competitiveness. However over the years, the government has tried to allocate some land to upcoming MSEs through its agents. These agents include local and provincial administration for Jua Kali sheds, KIE sheds and others (GOK, 2002). However such land gets "grabbed" by private developers due to absence of land title deeds.

Roads and other Infrastructure

Shortage of serviced sheds and other MSE stands further undermines the quantity and quality of MSE products. In-accessibility to land and lack of property rights hamper access to infrastructure and utilities by the MSES. Of particular importance amongst hindrances to MSES infrastructural facilities is access to water, electricity, bank, post office and other infrastructural facilities constrains MSEs technological adoption capabilities, thereby adversely affecting their performance and competitiveness of their products and services.

To solve this looming problem and enable Kenya to become a newly industrialized country (Nic) by the year 2020 as envisaged in the sessional paper No. 2 of 1996 on Industrial Transformation and Development, it requires a very invigorated injection of fresh skills and entrepreneurship. This will in turn promote and develop programmes for enhancing employment creation for the youth as well as provide investors with an abundant qualified labour force resulting in accelerated economic growth.

Importance of Small Businesses in Kenya

The Development of the small enterprise sector in Kenya is highlighted in the Sessional paper No. 1 of 1986, Sessional paper No. 2 of 1992 and the sixth National Development plan (1989 – 1993) as a primary means of strengthening Kenya's economy. The sector includes all enterprises employing 1-50 workers. The GOK recognizes the important contribution of the sector to the country's industrialization process as it is acknowledges that the sector creates the breeding ground for the small industries (GOK, 2004).

Thus the Economic Recovery Strategy for wealth and employment Creation acknowledges the role of the MSE sector in generating growth, creating jobs and reducing poverty (GOK, 2003). The paper expects over 88% of the 500,000 jobs promised to Kenyan citizens by the "Narc" Government at inception in 2002 to be created by the sector. According to the paper, the sector contributes about 18% of GDP and plays a critical role in easing foreign exchange constraints, in penetrating new markets and in stimulating growth and development in rural areas.

Strategies for Enhancing MSEs in Kenya

The Kenya Government since its inception has developed strategies and promotion programmes aimed at improving the economy by promoting small and medium enterprises. These programmes are either financial or non-financial. However, the most important of all these is the skills training as it is through personal development that an enterprise culture can be created (ILO/UNDP, 1990; Harper, 1983; Nelson, 1986).

2.2 Empirical literature

According to the Department of MSE Development, the MSE sector experienced substantial growth from 2000-2002, increasing to 2.8 million enterprises and MSE employment of 5.1 million persons, accounting for 74.2 per cent of total employment in 2002. This dramatic increase was due largely to retrenchment in both the public and private sectors.

However, the description of the MSE sector described in the following paragraphs is based primarily on data from the 1999 National MSE Baseline Survey.

According to the Ministry of State for Youth Affairs, youths are persons aged 15 to 35 years. These (youths) have considerable potential to contribute to the development of the nation. They form the largest segment of the Kenyan population. They contribute two thirds of the economically active population and account for 61% of the unemployed (GOK 2007), The Kenya demographic and Health survey of 2003 reported that young people are much more likely to be employed if they have completed their education (GOK/UNDP, 2003).

2.3. Research gap

From the above, it is clear that small enterprise sector is recognized as having potential to enhance job creation through establishment of industries and initiation of commercial enterprises (GOK, 2001). It is also clear that much has been done to promote programmes aimed at improving the Kenyan economy through promotion of SMES (GOK, 1992; GOK, 1997 and GOK, 1999).

Skills upgrading not only enhances employee technical and managerial skills but also increases MSEs ability to adopt new technologies. When incorporated in the introduction of new technology, skills upgrading has been shown to have a crucial impact on productivity as it involves experimentation, modification and adaptation to the enterprises (Enos, 1992; Awe and Tan, 1995).

Due to lack of adequate capital, youths are expected to be the major players in the small enterprise sector; yet studies show that 80% of these businesses fall within their first two years after start up (GOK,

2001). There exists no studies to explain this scenario and neither are there explanations as to why there is mass unemployment amongst the youth resulting to hopelessness, drug abuse and other social vices.

In conclusion no known studies have been done on Kenyan youths relating to their technology adoption and its effect on MSE performance. This research study is therefore aimed at investigating how youths are using their acquired technology to improve performance of their MSES .It is based in Makueni District.

3.0 Research Methodology

3.1 Research Design

The study used both qualitative and quantitative research designs. Quantitative research design would help in revealing the direction and strengths of the variables while qualitative design would show the main themes. The design was descriptive in nature; as Gall and Borg (1989) noted, "Descriptive studies by nature emphasis interpretation".

.

3.2 Target Population

The target population for this study was youth led MSEs in Makueni district who received any form of technology between 2000 and 2007. The total number of all MSES in the district was estimated at 1320. Assuming those led by youths were 30 %(as youths are 30% of total house holds (GOK, 2006)) our target population became 396.

3.3 Sampling Method

Systematic random sampling technique was used to get a study sample of 119 out of a possible 396 youth led SMES in Makueni District. Stratified random sampling technique gives all target population within a stratum an equal chance of being selected.

3.4 Data Analysis and Presentation

Qualitative data was manually analyzed using the researcher's insight and research skills to bring out the main themes. The emerging themes were then operationalised for content analysis and to make meanings and importance of the study.

4.0 Summary of the Findings

4.1. Response Rate

The research proposal expected to collect data from a target population of 119 eligible respondents. However some entrepreneurs had gone out of businesses. Others were too busy to fill in the questionnaires and a few others were totally not available for the interview. The number of respondents who were finally interviewed was therefore 103 out of the sampled 119.

According to Neuman {2000), active response rate is calculated as follows:

$$na = \frac{\text{Total response}}{\text{Total No. of sample-\{ineligible+ un reachable}}$$

In our project, active response rate becomes

$$\frac{103 * 100}{119 - 4} = 89.6, \text{ say } 90\%$$

Willimack (2002) suggested that response rate for North America ranges between 50% and 65%. Healey (1991) said 50% for postal survey and 75% for face to face interviews is sufficient. Neuman (2000) recommended 10% to 50% for postal surveys and 90% for face to face as reasonable. Our survey, being a researcher administered takes cognizance of all the above scholars' recommendations.

4.2 Data Analysis

This section presents graphical analysis as well as descriptive statistics of the variables used in the study and which conforms to Gall and Borg (1989) observations that "descriptive studies by nature emphasis interpretation". Data was collected using a predominantly 5 point likert type scale. The choices were coded and so also were the questions to facilitate analysis.

4.3 Inferences

From the discussions, the following deductions came out strongly;

Technology was rated highly as of major help in solving customer complaints as well as retaining them, in keeping business records, coping with market competition, incorporating innovations and product differentiations, motivation of employees as well as identifying refinancing needs. On business competitiveness, technology was seen as very effective in increasing sales volume, improving product quality as well as increasing production efficiency.

For technology adoption forms on performance of youth led MSEs, there was a general consensus that youth led MSEs have investment in technology in different ways. However, Pearson's correlation matrix showed a very weak correlation index, (very close to zero), implying that technology adoption forms have had very little effect on performance of youth led MSEs. This makes the forms not effective in enhancing performance of youth led mses, a possible reason why many MSEs fail within their first two years of operations (Nelson, 1986).

Youths think they have all the technology they need to manage their businesses. However they do not realize that these technologies do not get translated into business results. Three possible reasons for this are

(i) That what youths are using is not appropriate technology
(ii) That if youths are using appropriate technology, then the adoption methods are inappropriate
(iii) That youths are not empowered (do not have basic capacity) to adopt the technology, to assimilate the technology, to manage it and to control results with it (UNIDO, 2004)

4.4 Responses to Research Objectives were summarized as follows

To Investigate Whether Technology Affects Quality of Youth Led MSE's Products and Services

Most respondents perceived that technology is of much help in improving quality as well as increasing sales volume of the products. However there is minimal correlation between technology in use and MSEs performance. Major challenges experienced are insufficient finances and irrelevant skills.

To Determine if Technology Influences Acquisition of Financial Resources In Youth Led MSEs

Most entrepreneurs perceive that technology in use helps them much in their financial resources management as well as in acquisition of these resources. As a result, this improves their business performance fairly well. However, Pearson's correlation matrix shows a very weak correlation between financial resource management and MSE performance. A major challenge affecting financial resource management is shortage of funds and provision of cheap loans is suggested as an intervention measure.

To Find Out if Technology Affects Productivity of Youth led MSEs

Most entrepreneurs felt that technology is of much help in improving their MSE productivity. However a few of them did not feel its effect. Pearson's correlation matrix shows a very low correlation between the technology and MSE performance. Major challenge in using the technology include inefficient machines and a major intervention measure suggested to enhance effectiveness in the technology is provision of finances, training and provision of efficient machines.

To determine if Technology Affects Sustainability of Youth Led Mses

Most respondents felt that through technology, they were able to conform to legal requirements. In turn, this impacts very well on their business performance as well as their sustainability. However there seems a very weak correlation between conformance to legal requirements and MSE performance. A major challenge in conforming to legal requirements is high license fee. Major intervention measure suggested to enhance conformance to legal requirement is that authority should reduce license fee**.**

To Investigate if Technology Affects Marketability of Youth Led MSE's Products and Services

Most respondents feel that technology used enhances their ability to secure good business site. This in turn improves their products and services marketability and thus business performance very well. However there is a weak correlation between current business locations and MSE performance. Major challenges regarding business location include unavailability of a well sited business premise and high rent charged by landlords. A major intervention measure suggested is provision of cheap industrial parks.

5.0 Conclusions and Recommendations

5.1 Conclusions

The following conclusions were derived from the research findings.

There is a general consensus that all entrepreneurs have invested in technology in different ways. This technology has helped MSEs in different ways, key among them being improvement of product quality and production efficiency. However there seem to have been no correlation between technology adoption forms and performance of youth led MSEs. This makes the forms not effective in enhancing performance of youth led MSEs, a possible reason why many MSEs fail within their first two years of operations as observed by Nelson (1986).

Most youth entrepreneurs are young with no or little financial resources. As a result, they were able to invested in only one form of technology; training.

Though technology is perceived as being of much help to the business, it does little in human resource management. It is therefore not helping youth led MSEs much due to insufficient finances and irrelevant skills

5.2 MSE Technology Adoption Model

The above conclusions may be summed up in form of an MSE technology adoption model which shows that dependent variables are a function of investment in technology. Consequently, these variables affect performance of MSE which in turn influences the type of investment in technology that the MSE adopts.

As youths start their own enterprises, they have very little capital, little business experience and have not established much business networks. They will therefore not be performing well and will invest mainly in training and purchase of the little equipment that they need. This minimal investment in technology will result to inadequate and inappropriate technology adoption forms, and consequently to ineffective MSE performance. This vicious circle of poor performance may however be broken at any level through some intervention measures.

As the MSE breaks this vicious circle of poor performance and moves to the next level of performance, they will have more resources and business networks and will recognize the need to invest more in various types of technology. This will result to better technology adoption forms and consequently to improvement in their MSE performance. This process goes on and on and thus becomes cyclic in nature. The figure below shows this relationship

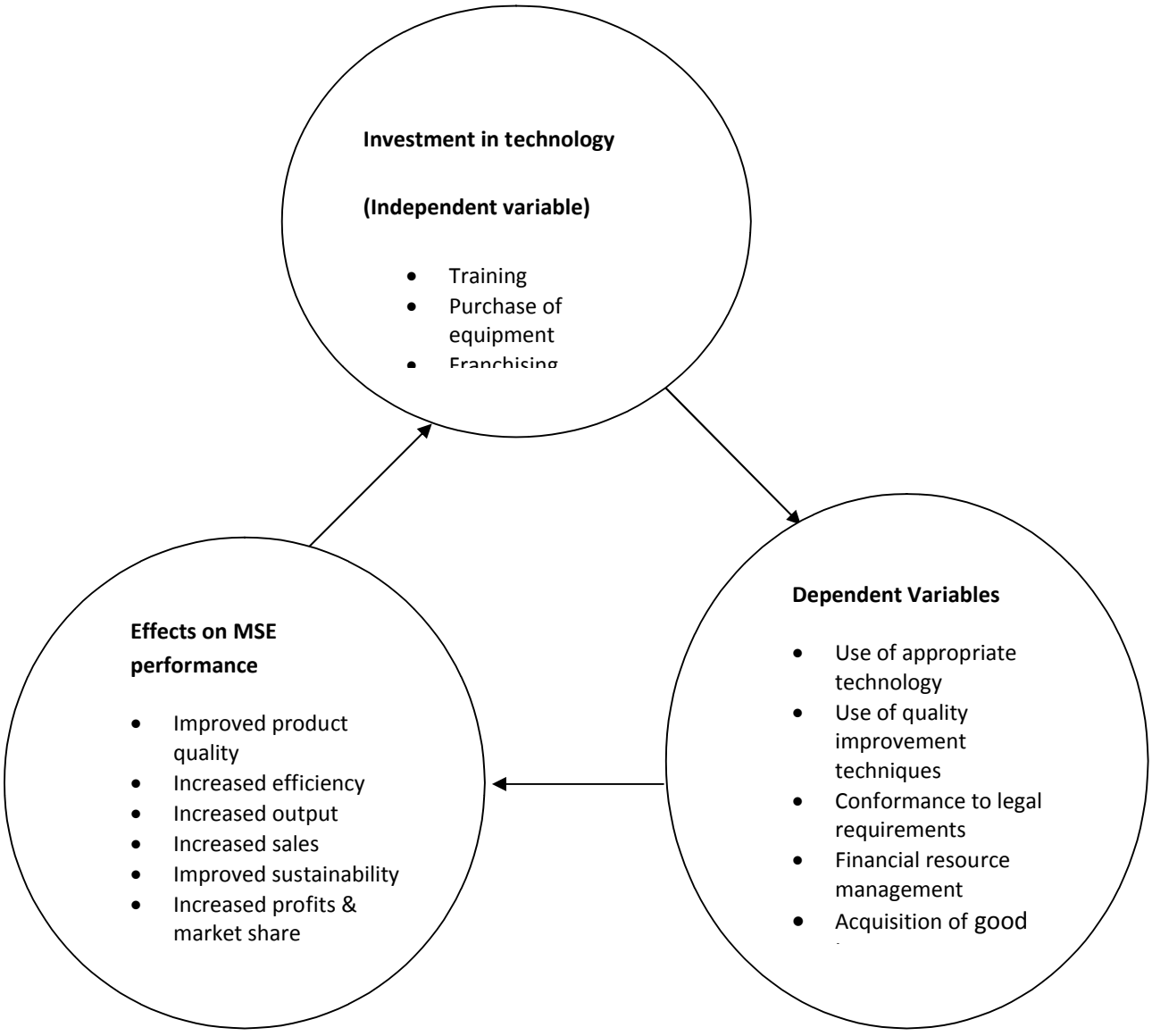


Figure 2: MSE Technology Adoption Model

5.3 Recommendations

For technology to be effective, all its different forms need to be available to compliment each other. Youth entrepreneurs therefore need to be encouraged and supported by the government or by another body through the government to invest in all the types of technologies (training, equipment, sub-contracting and franchising

To enable MSEs cope with challenges of financial resources, it is recommended that the government of Kenya provide them with accessible, cheap and adequate loans. The current youth fund was started for this purpose but unfortunately the group component is not enough and neither does it assist individual entrepreneurs. Individual component of the youth fund through micro financing institutions is feared due to the bad effects associated with failure to pay bank loans.

To cope up with challenges associated with unavailability of business premises, it is recommended that the government need to construct adequate industrial parks in rural areas of the country

Finally, it is highly recommended that youth entrepreneurs be given a forum where they can air their views concerning issues affecting their businesses, a situation which would build their confidence in entrepreneurship and business management skills.

5.4 Research Gaps

To improve technology adoption processes amongst youth led MSEs, the following topics are suggested for further researches,i.e., effect of technology on human resource management amongst youth led MSEs and relationship between technology and firm productivity amongst youth led MSEs.

References

Ablu, M. (1997). Technological learning and innovating in industrial clusters in the south" science policy unit, electronic working paper No. 7 Brighton: university of sussex.

Argris c. (1985). Strategy, change and routines, New York, Pitman.

Aw, B. and Tan, H. (1995)."Training Technology and Firm-Level Productivity in Taiwan (China)." Conference on Enterprise and Training Strategies and Productivity. World Bank, June 1995.

Awasthi, D. N. and Murali, B. P. (1990). Entrepreneurship Development and New Enterprise creation, Experience of the entrepreneurship Development Institute of India. ILO Geneva.

Biggs, T., Shah, M. and Srivastava, P. (1995). Technological capabilities and learning in African enterprises, technical paper no. 288, Washington DC, World Bank.

Deakins, D. (2003). Entrepreneurship and Small Firms 3rd ed. MC. Graw Hill, New York.

Drucker,(1986). Innovation and entrepreneurship Heinemann publishers,London.

Embu (2001). Embu District Development Plan (2002-2008) on Effective Management for sustainable growth and Poverty reduction, Embu County Council, Embu.

Engelman, R. (1993). J*ua* Kali Development Project, Management Training KIM, Nairobi.

Enos, J.(1992). The creation of technological capabilities in Developing Countries, London: pinter.

Fulop, C. (1970). Retailing and the consumer printed by Longman Group LTD London.

Gall and Borg (1989). *Educational Research, an introduction (5thEd)* New York and London, Longman.

Gibb, A. A. (1991). Defining success in Entrepreneurship Approach, ILO Geneva.

Gichira R. (2002). Policies, Strategies and Programmes for Enhancing the Participation of Small and Medium Enterprises in E-Trade. Paper Prepared for Ntfecom's Strategic Workshop Held at Safari Park Hotel, 20th April, 2002.

Gichira, R, Amondi, R., Njoroge, J. and Kabugua, M. (2002). E-Trade bridge programme for Kenya, a draft for discussion ,International Trade Centre.

Government of Kenya (1986). Sessional Paper No.2 of 1986 on Economic Management for renewed Growth. Government Printers, Nairobi.

Government of Kenya (1989). Strategy for small enterprise development in Kenya towards the year 2000 Government Printers, Nairobi.

Government of Kenya (1996). Sessional paper No. 2 of 1996 on Industrial Transformation to the year 2020. Government Printers, Nairobi.

Government of Kenya (1997). 8th National Development Plan (1997-2000*).* Government Printers, Nairobi.

Government of Kenya (2004). *(*22nd Jan. 2004) Draft Sessional Paper on Development of Micro and small enterprises for wealth and employment creation for poverty reduction. Government Printers, Nairobi.

Government of Kenya (2004). Central bureau of statistics, Government Printers, Nairobi.

Government of Kenya (2005). Economic recovery strategy for wealth and employment creation: 2003 – 2007, Nairobi.

Government of Kenya (2006). Ministry of state for youth affairs, Draft strategic plan 2006-2011, March 2006. Government Printers, Nairobi.

Government of Kenya (2007). The National youth Policy, Government Printers, Nairobi.

Green law and Biggs (1979). Modern personnel management printed by W.B Sounders Co. USA.

Guthrie, C. (1983). Selection and training for entrepreneurship Development ILO Geneva.

Hammer, M and Champy, J. (1983). Re-engineering the corporation – A manifesto for Business revolution, Nicholas Brealey, London.

Harper, M. (1993). Selection and training for Entrepreneurship Development ILO Geneva.

Healey, M. J. (199). Obtaining information from business. Harlow, Longman).

Hernes, T. (1988). A guide for trainers and training managers, ILO Geneva.

Ikiara, M. and Okatch (2005). Services trade related development strategies in tourism, ILO (1986). The promotion of small and medium sized enterprises ILO, Geneva.

Kasina, C. K. (1991).“ Directorate of industrial training” News letter.

Kelly, C, et al. (1969).How to organize and Operate a small business Printed by prentice-Hall ,Inc Toronto Canada.

Liedholm, C and Mead, C. (1991). Dynamics of Micro-enterprises Research issues and approaches, Michigan State University.

MC Comic, D. (1988). Small enterprise in Nairobi; A golden opportunity or dead end? PhD Dissertation, University of Nairobi.

Morrison, A, (1998). Entrepreneurship – an International Perspective Butter worth Heinemann.

Moyi E and Njiraini, P. (2005). Towards Technology models for MSES in Kenya: common principles and best practices Kippra Discussion paper NO. 51. Bulletin.

Mugenda and Mugenda(1999). Research methods, quantitative approaches. Act press, Nairobi Kenya.

Neuman, W. I. (2000). Social research methods, 2nd ed. London, Allyn and Bacon.

Ngahu, C. (1995). Choice of technology in small-scale enterprise: International Development Research Center (IDRC).

Nzomo, N. D. (1986). Entrepreneurship development policy in National Development Planning__The Kenya – Case Article Eastern Africa Economic Review.

Oakland, J. S. (1993). Total quality management –The route to improving performance, 2nd edition, Butterworth – Heinemann Oxford.

.

Oakland, J. S. (1995). Total quality management – Text with cases, Butterwoth – Heinemann, Oxford.

Oakland, J. S. (1999).Total organizational excellence –Achieving word class performance, Butterworth –Heinemann in Oxford.

Powell, V. (1987). Improving public enterprise performance ILO Geneva.

Sifuna, D. (1986). Unemployment and non-formal training in the informal sector in Kenya.

Presented to a staff graduate seminar, held in Kenyatta University. Nairobi.

Stevenson L. and Onge A. (2005). Support for Growth Oriented Women Entrepreneurs in Kenya, African Development Bank, Tunis.

UNIDO (2002). Industrial development report: competing through innovation and learning venna: united Nation industrial development organization.

UNIDO (2004). Integrated institutional capacity building services and programmer for technology centers and parks venna: United Nations industrial development organization.

Van Dijki (2001). Innovation and micro and small enterprise development in developing countries: linking knowledge as skills to produce employment: University of Erasmus Netherlands.

Willimac, D. K. (2002). Understanding unit and item non response in business surveys, Wiley Inter Science,New York.

World Bank (1978). Appraisal of small-scale industrial project Kenya Washington, DC.

Yambo, M. (1986). Technical Training and Work Experience in Kenya – unpublished.

PARTICIPATORY MAPPING OF HISTORICAL CHANGES OF WATER RESOURCES IN THE RIVER BUATHONARO CATCHMENT IN MERU COUNTY, KENYA

C. Ngeera[1], J. M. Gathenya[2] and P. G. Home[3]
[1,2,3]Biomechanical and Environmental Engineering Department, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
E-mail: ngeerac@yahoo.com

Abstract
The historical changes of water resources in River Buathonaro catchment were investigated using participatory GIS and local historical knowledge of Water Resource Users Association (WRUA) of the catchment. The study mapped and characterized all the springs and streams in the catchment, indicating their status as either permanent, seasonal or completely dry. The time periods when the status changed were also noted. Between 1970 and 2007 seventeen springs and five streams completely dried up. Currently, only thirty two out of fifty nine springs in the 70s are flowing permanently. These results were presented as time series maps and databases showing the changes. Through the involvement of WRUA as co-investigators, the knowledge generated by the research is appropriated at the local level. This in line with the Water Act 2002, which elucidates the need for active involvement of local communities in accounting and managing local water resources. The output of this work illustrated a constructive blend of authors' knowledge of catchment and the local community detailed knowledge of local hydrology. The study findings elicit various policy interventions and the need for further research.

Key words: PGIS, Buathonaro catchment, historical knowledge, water resources, Kenya

1.0 Introduction

Water resources in Buathonaro are under intense pressure from anthropogenic activities, and there are concerns about the catchment declining water resources. Despite this, little has been done to capture the extent of the problem. The prevalent water crisis in the catchment (DAAD, 2006), has prompted the local water resource users association (WRUA) to seek ways of conserving and managing the declining water resources. However, lack of relevant local data has hampered efforts to manage the resources. Thus, there is a need to get up-to-date information on the changes occurring on the water resources. In order to get precise information, participatory approaches, which are now major tools used in natural resource management (Chambers, 1994a; Shah, 1993; Devavaram, *et al.,* 1991), were used.

In the Kenyan context, participatory approaches in water resource management came into prominence after the water sector reforms of 2002. In this study, historical knowledge of the water resources changes was obtained from the local community using participatory techniques, local community historical knowledge and participatory GIS (PGIS).

Natural resource management strategies worldwide emphasise the importance of incorporating the knowledge and perspectives of local stakeholders (Chambers 1994; Rhoades 1998; Hinchcliffe, Thompson *et al*., 1999). Institutionally, Kenya has allowed local communities participation in development and management of local water resources through formation of water resources users association (Water Act 2002).

Geographic Information Systems (GIS) has become an important tool for natural resource monitoring and representation of spatial information (FAO, 1997). GIS technology offers capabilities with which resource managers can adopt to create and alter resource plans and also incorporate new conditions when environmental conditions change. GIS is designed to support the capture, store, management, manipulation, analysis, modelling and display of spatially referenced data for solving complex planning and management problems.

Increasing public concern regarding water quantity and quality monitoring has led to a rise in the use of GIS and other related technologies. According to Warnecke *et a,* (2002) water is the most fragmented, overlapping and confusing natural resource – but the analytical capability of GIS technologies can help to manage land and water related conflicts (Berry 1994). Some examples of applications of GIS in water resources management are summarised in Table 1.

Table 1: Applications of GIS in water resources management

Applications	Citation
GIS-based watershed management system for identifying wetland areas in the Welland River channel.	(NPCA, 2003)
Preparation of 3-dimentional GIS based model to delineate sediment deposition zone in the Clich River.	(NPCA, 2003)
GIS-based decision support to investigate the interaction of water quality management and climate variability and change.	(Levine et al., 1996)
A State wide GIS database that include soil, topography, vegetation, hydrography and land ownership to address wetland prioritization projects.	(Knight et al., 2000)

Source: Baral 2004

New GIS concepts are emerging that involve both the practitioners of the technology and the benefactors of spatial information products. Emerging concepts include participatory GIS (PGIS) which has developed out of a merger between participatory methods and Geographic Information Systems (GIS). This new GIS initiative aims to develop a system that is "adaptable to inputs from ordinary citizens" and other non-official sources (Obermeyer, 1998).

PGIS combines a range of geo-spatial information management tools and participatory techniques to represent peoples' local spatial knowledge in the form of virtual or physical maps (URISA 2002), which show the communities' perceptions of resources and landscape knowledge (Rambaldi and Callosa 2000). The PGIS created knowledge base system stands as an interface between the scientific knowledge system and indigenous knowledge systems (Scoenhoff, 1993), relating the two to bring out the best in decision making.

The PGIS project uses a range of approaches including mental mapping, participatory sketch mapping, transect mapping and participatory 3-dimensional modeling that are commonly associated with Participatory Learning and Action (PLA) initiatives (IFAD, 2009). These participatory strategies are reinforced with more technical tools including Geographic Information System (GIS), Global Positioning Systems (GPS), aerial photographs, remotely-sensed images and other computer-based spatial technologies (ibid).

PGIS has been adopted in many areas such as protection of indigenous land rights (Jarvis and Stearman, 1995; Nietschmann, 1995), record and appraise local knowledge (Nietschmann, 1995) mitigate resource conflicts (Kyem, 2006), and to assess local needs (Craig and Elwood 1998; Ghose, 2001). Other community-based GIS applications have sought to increase community access to information and resources (Elwood 2002; Laituri, 2002), incorporate local knowledge into national land reforms (Harris and Weiner, 2003: *Weiner et al*., 1995).

The main objective of this paper was to capture the historical changes on water resources, while the specific objectives were:

(i) Identification of the locations of springs, streams and wetlands in the catchment.
(ii) Establish the streams and spring that have dried up in the catchment.
(iii) Initiation of catchment GIS database on water resources.

2.0 Description of the Study Area

The catchment is 150 Km^2 and lies between approximately 2,050 m above sea level in the upper sections and about 700 m above sea level in the lower parts. The catchment is bounded by latitude 37° 53| 00|| E and 38° 05| 00|| E and 0° 12| 00|| N and 0° 21| 00|| N.,(Figure 1). The catchment contributes to maintenance of water resources, agriculture, forestry and tourism development.

The altitude ranges from 2060 m a.s.l to 700 m a.s.l the climatic conditions range from humid to semi-humid. Rainfall is bimodal coming during the long rainy season of March to May to the short rainy season from October to December. The mean annual rainfall range between 1000 mm and 1500 mm.

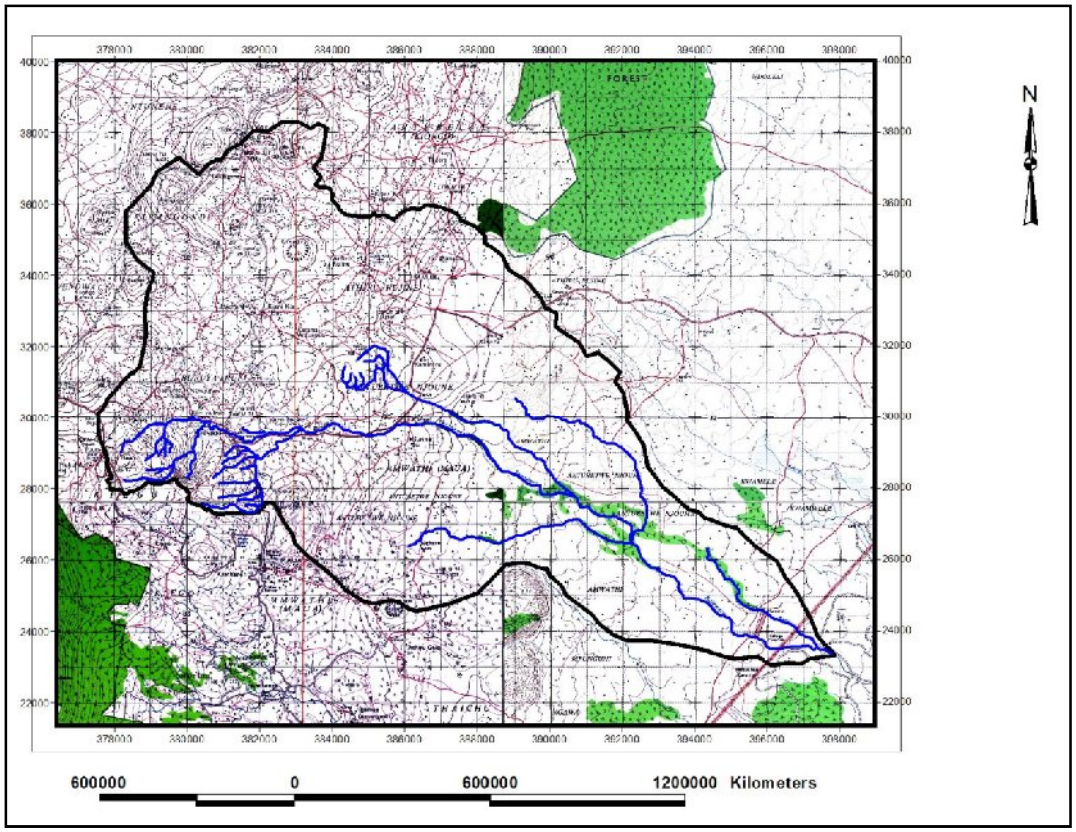


Figure 31: Location of River Buathonaro Catchment

3.0 Methods and Materials

3.1 The Research Methodology

3.1.1 Pre-field

This study relied principally on a combination of participatory field methods and GIS following. GIS was used primarily as a tool of analysis and presentation. Participatory field methods were selected to gather data on the kind of seamless experience and knowledge local participants have of their environment.

3.1.2 Base Map Preparations

Panchromatic aerial photographs of years 1967 were arranged in order of the flight sequence and 60% overlap and viewed under stereoscope to delineate the catchment drainage system. The photographs with the delineated area were scanned and a mosaic of the images was formed using ENVI 4.0 and geo-referenced using ArcView 3.2 (Figure 2).

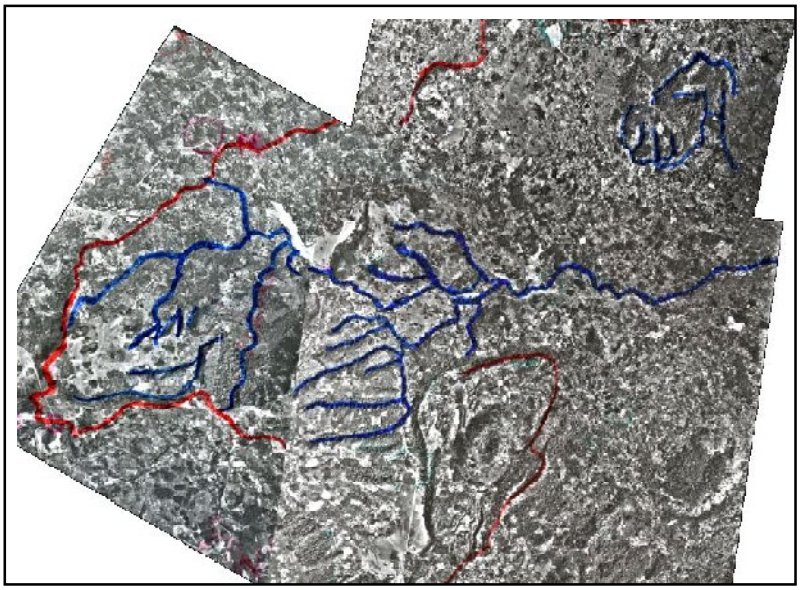


Figure 2: Mosaic of aerial photographs with delineated drainage system

The mosaic was overlaid on the topographical map of the catchment and the delineated drainage system digitized (Figure 3).The digitized drainage system was harmonized with the river line of River Buathonaro to produce the drainage network of the catchment, which clearly showed the first order streams of River Buathonaro (Figure 4).

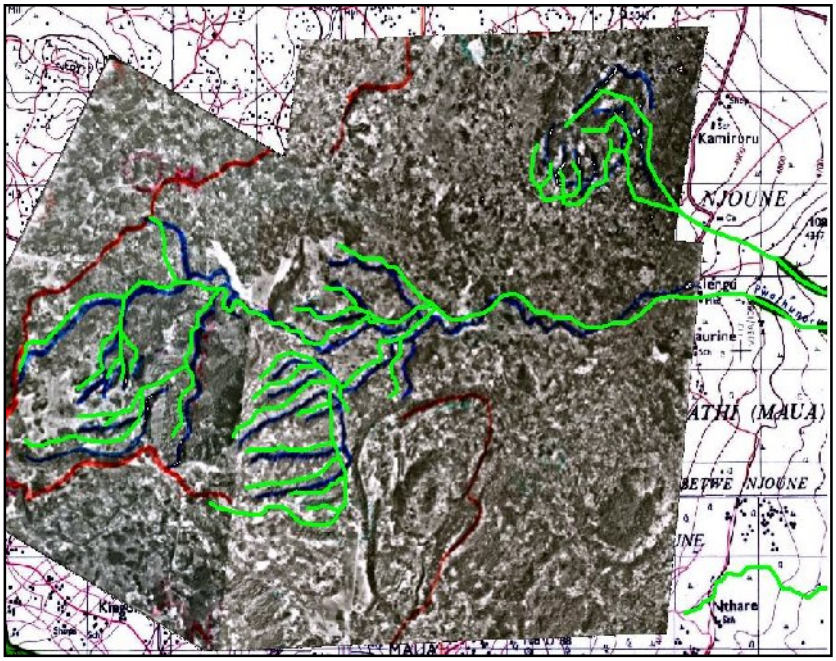


Figure 3: Mosaic overlaid on the topographical map of the catchment

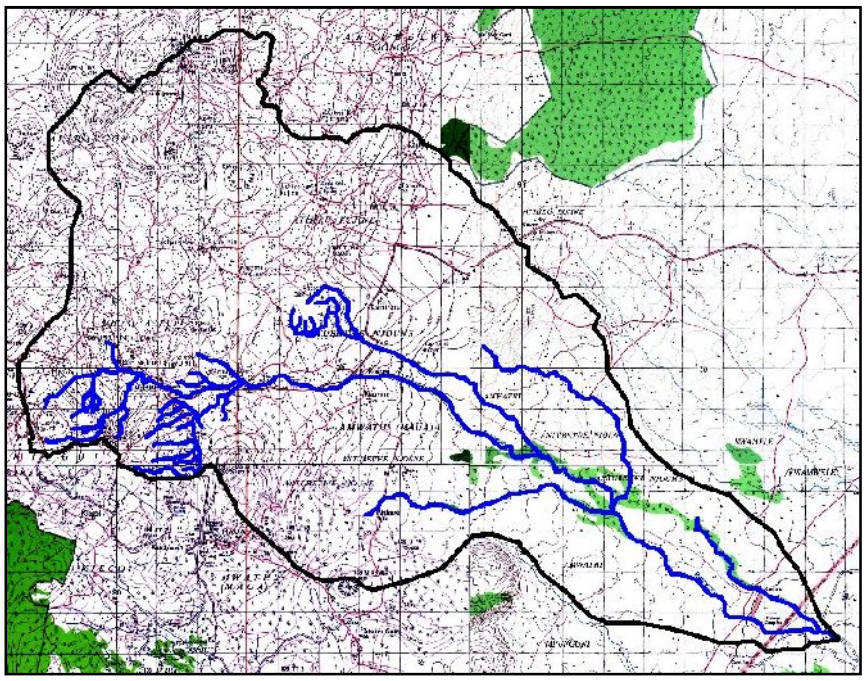


Figure 4: Drainage network of the Buathonaro catchment

The base map of the catchment was prepared from the topographical map and included digitized roads, streams, swamps and GPS points of all the springs in the catchment (Figure 5).

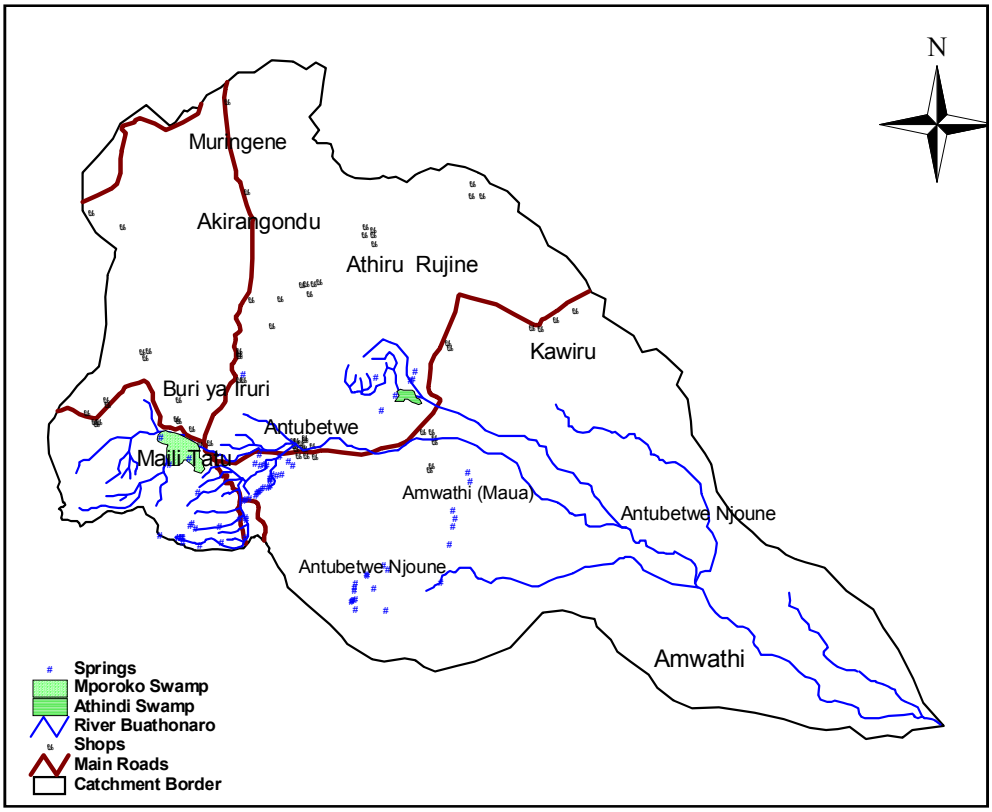


Figure 5: Base map of River Buathonaro Catchment showing spring and streams

3.1.3 GIS Data Collection

Collection and preparation spatial data for GIS use is usually the most expensive and time consuming as noted by Wing and Bettinger (2003) and Lo and Yeung (2002), component of any GIS project. Therefore in this study, efforts were made to obtain and use GIS databases that already existed and are relevant for the purpose (Table 2).

Table 2: GIS databases that already existed

GIS Data	Source	Purpose in the study
Catchment Arcview shapefiles	Authors previous study in the area	Delineation of the catchment of images
Aerial photos	Kenya survey	Delineation of first order streams

Source: Authors 2008

3.1.4 GIS Software

Accessibility of existing GIS database, ease of integrating information from existing sources were the main criteria used in the selection of software. Arc View GIS 3.2 software with extensions was selected for the project, for following reasons:

(i) Available at the University BEED Labs.
(ii) As desktop software it can be set up easily on laptops to carry in the field.
(iii) Simple to integrate with Garmin GPS and to download the GPS data.

(iv) An ArcView extension DNR Garmin was available free of cost.
(v) Ease of operation (the software).
(vi) Ease of both standard and on-screen digitising.
(vii) The authors familiar with this software.

3.1.5 GPS Equipment

A handheld GPS (i.e., Garmin GPS e-trex) was used in this research project and provided good level of accuracy it was adequate for the purpose of this study. In addition, the GPS can store the locations of points and data that can be downloaded to a PC using a PC interface cable and free software (e.g., DNR Garmin extension for ArcView 3.2).

3.1.6 Field Work

The field work involved 10 members of the Buathonaro Water Users Association (BWARUA).The members were involved in all aspects of the research including survey design, data collection, analysis and the presentation of the results. The members selected had lived in the catchment since the 1970s and had good knowledge and experience of the area.

The participatory investigations tools (maps, sketches, diagrams) were used first. The participants in each study area were provided with sheets of white paper and asked to draw resource maps of the study areas according to their perceptions. The participatory investigations took the form of semi-structured interviews on local farming practices and water resources management information was gathered on water sources, shortages, perception of water quality, and land use/cover changes

The GPS locations of all the springs and streams in the catchment were captured, as directed by the BWARUA during the transect walks. For each spring and stream the following data was collected, the local name, current and the past status of the springs (either permanent or seasonal), past and current LUC around the spring and dates of when springs and streams dried or turned seasonal were also noted. Interviews and preliminary results were reviewed and validated by the group daily in the field, with the authors behaved mostly as active listeners and observers. The survey results were compiled and analyzed and validated jointly by the BWARUA and the authors.

3.1.7 Post-Field

The data obtained included location of streams, springs and main roads. The data was transformed into geographic data using a Global Positioning System (GPS), entered into a GIS format (ArcView 3.2) and overlaid with the base map of the study areas in order to produce a geo-referenced time series maps.

4.0 Results and Discussion

Results were summarised into time series maps that showed the changes on water resource over time. The maps were readily recognized and adopted by the local community since the community was involved in the research through BWARUA. Comparing 1970s and 2007, BWARUA pointed out that, less springs and streams are flowing, some have turned seasonal and others have completely dried up.

Seventeen springs have completely dried up, ten springs turned seasonal while fifteen others have significantly reduced flows. Currently only thirty two out of fifty nine springs in the 70s are flowing permanently (Table 3). Data obtained was used to make three time series maps, which depicted the changing status of the springs (Figures 6, 7 and 8) and streams (Figures 9 and 10).

Table 3: Status of springs

	BWARUA Description	Author's Description	By end 1980s	By end 1990s	By 2007
1	Spring flowing normally as far as it could be remembered	Permanent springs	59	48	32
2	Springs whose flows have reduced compared to 1970s, but still flowing throughout the year.	Springs with reduced yield	10	14	15
3	Spring not flowing throughout the year.	Seasonal springs	5	8	10
4	Spring that were flowing in the 1970s but have completely stopped flowing. (no flows at anytime of the year)	Dry springs	0	4	13

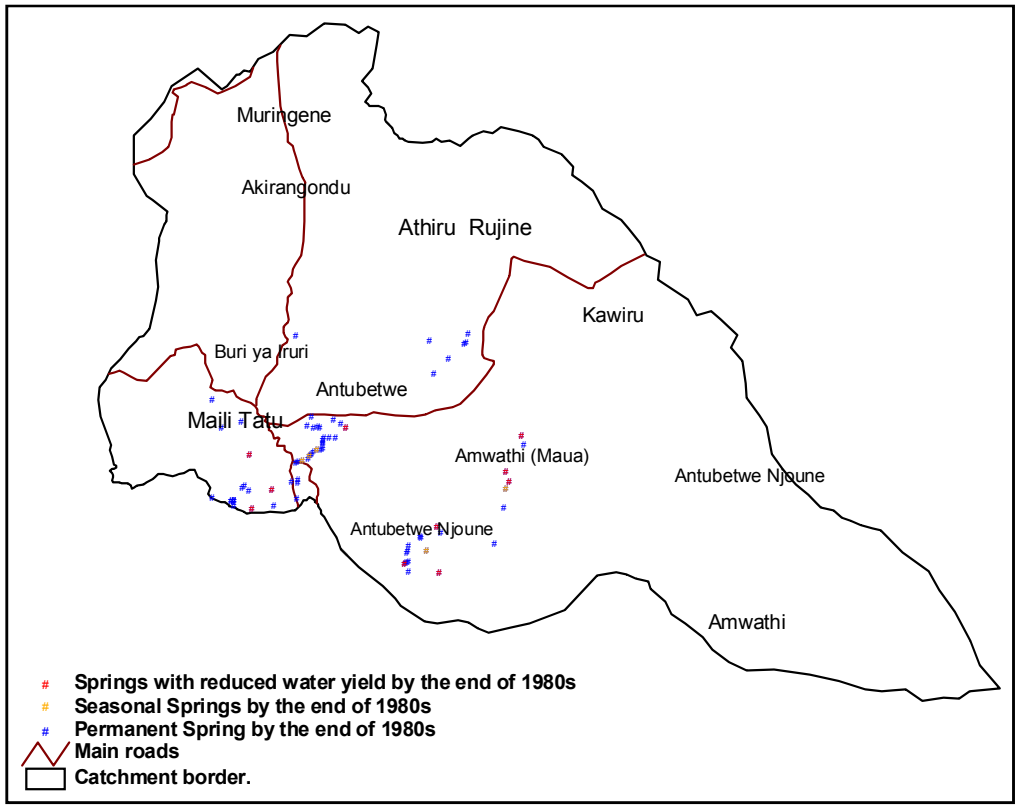


Figure 6: Status of the springs by the end of 1980s

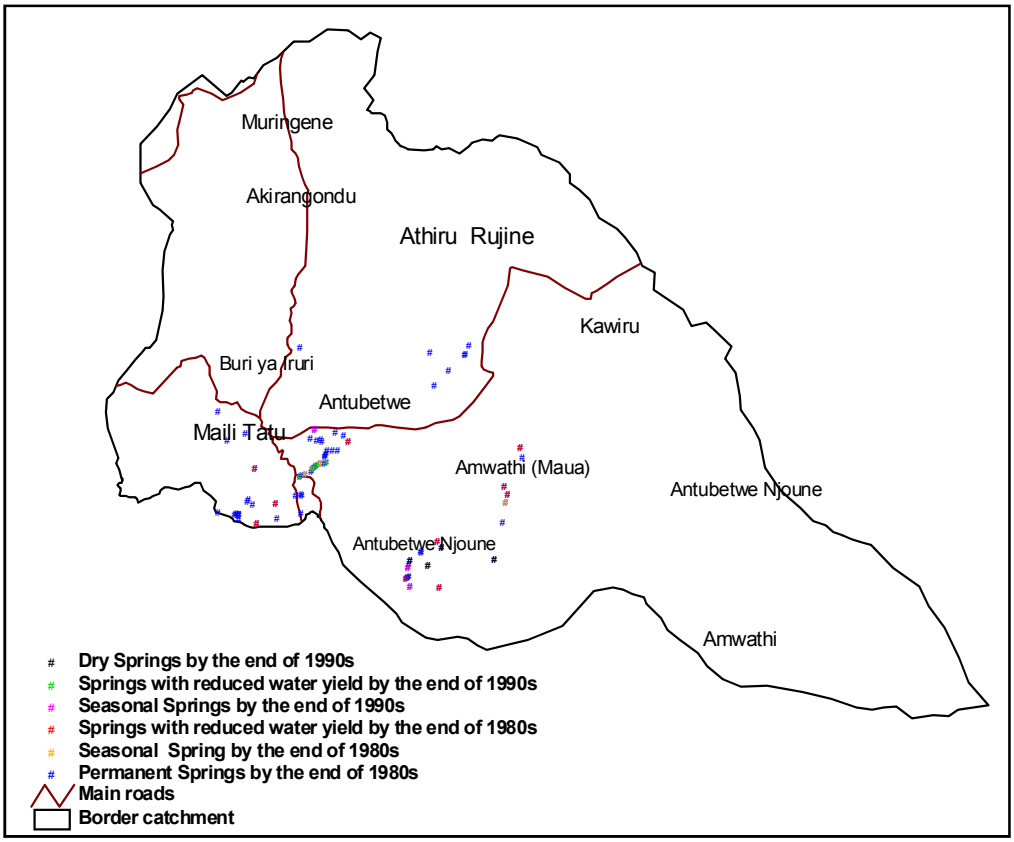


Figure 7: Status of the springs by the end of 1990s

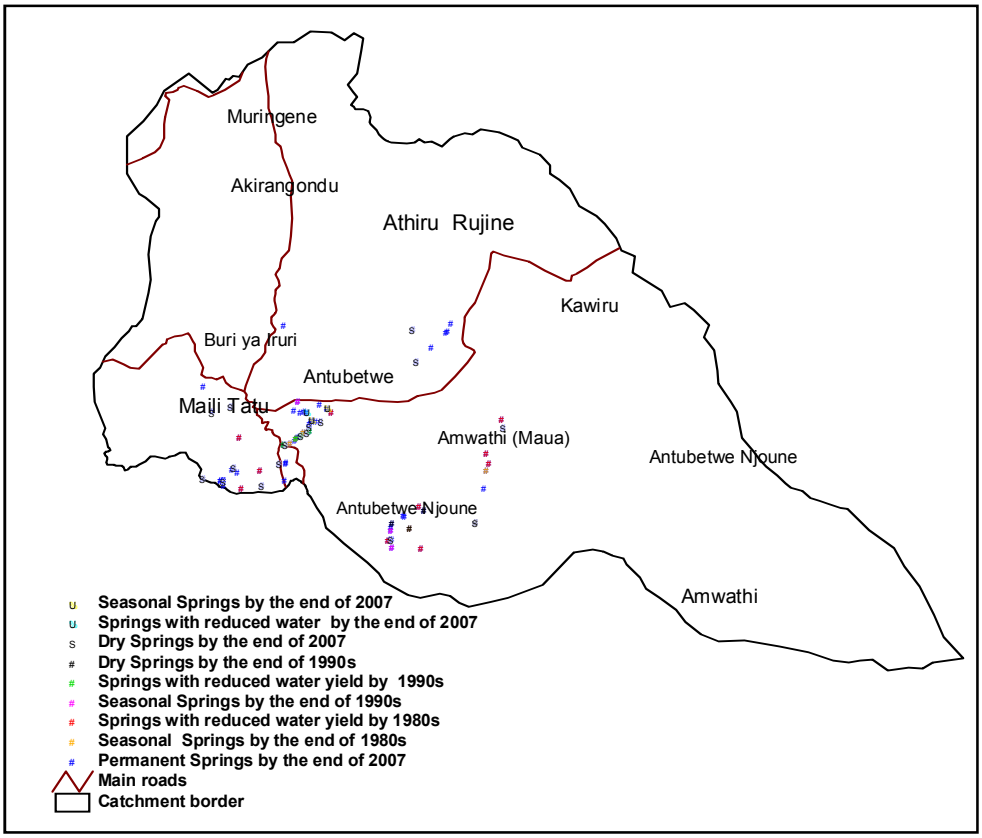


Figure 8: Status of the springs by the end of 2007

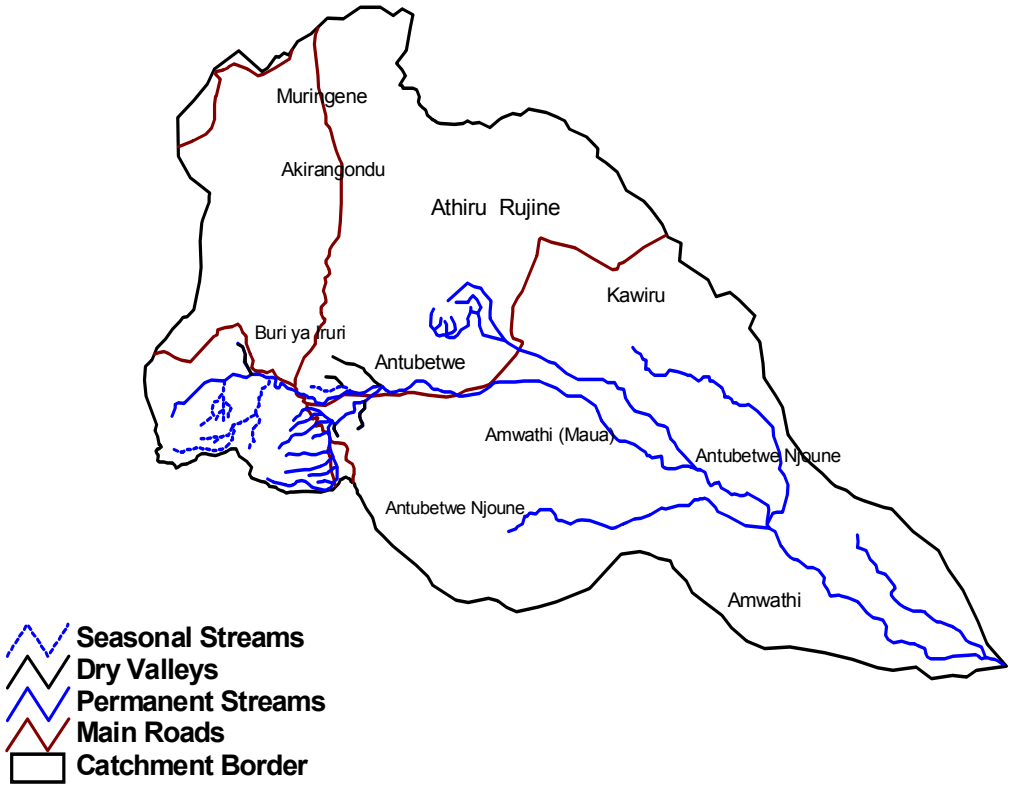


Figure 9: Status of Buathonaro catchment Streams in by the end of 1980s

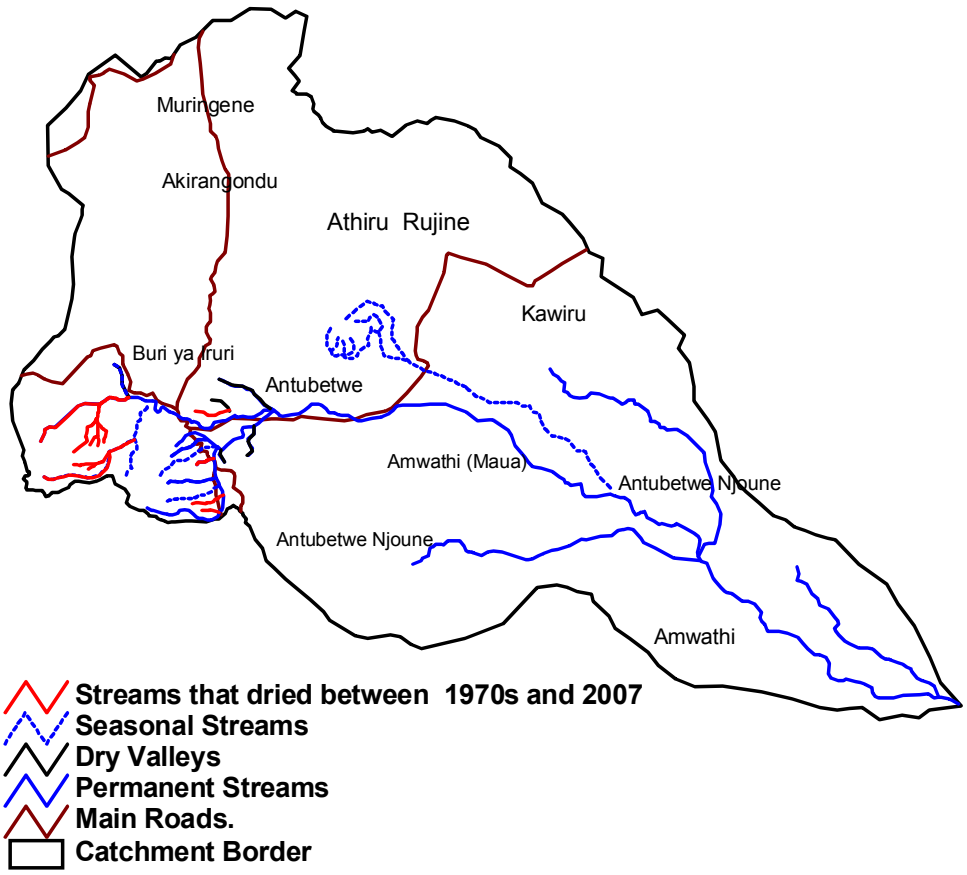


Figure 10: Status of Buathonaro catchment streams by 2007

4.1 Community Perception on the Historical Water Resource Changes

Community concurs that the flow of River Buathonaro has declined considerable compared to the situation in the 1970s. BWARUA attributes the decline to the loss of the zero and first order ephemeral and perennial springs and streams. These springs and streams are important tributaries of the River Buathonaro. The decline of River Buathonaro has affected the livelihoods of people relying on the springs and streams for domestic use, livestock and farming.

The local community blames the loss of springs and streams to the land use/cover change that have occurred in the catchment leading to large scale removal of forest both on the banks of the streams and the surrounding Nyambene Ranges, encroachment of wetlands and destruction of the headwater region by human activities. Illegal abstraction of the streams and planting of exotic species of trees especially eucalyptus especially in the head water and in the wetlands was also mentioned as the cause of decline of springs and streams.

The WRUA contends that water degradation was because the community was previously, ignorant of the impacts of human activities on the catchment. The WRUA also explained that before the water sector reforms, the community was not involved in the management of the watershed leading to conflicts which hampered sustainable management in the catchment area. However, after the reforms there has been greater community participation in the sustainable management of the catchment

through the formation of water user associations which police resource usage especially water resources.

4.2 Strengths and Limitations of PGIS

Baral (2004) contends that there is general agreement in the international literature that the use of PGIS can enhance people's participation in resource management, but still GIS has the possibility of marginalizing less technologically skilled communities. In light of this, the authors of this paper' assessment of the literature, revealed that the strengths of using PGIS outweighed the limitations in the case of River Buathonaro. Limitations as highlighted by Baral (2004) were overcome by proper planning which involved the community from onset of the research and paying special attention to the views and opinions of BWARUA. The main limitations encountered in this research were in relation to the time taken to interact and gain the trust of community members.

5.0 Conclusion

The research aimed at using indigenous knowledge of WRUA on water resource to assess and document the changes that have occurred on the resources. The results reveal that indeed there have been changes which are undesirable, as evidenced by the loss of spring and streams. The community attributes loss of springs and streams to land use/cover changes caused by human activities.

PGIS was used to spatially capture the indigenous knowledge, which was used to develop accurate geo-referenced information that was recognized and readily adopted by the local community and the researchers. It also greatly facilitated the research process by enhancing trust-building, as the communities appreciated the fact that the researchers acknowledged the value of their own local knowledge.

Lastly, the results of this study will be useful in designing appropriate catchment management strategies and plans which will help in elevating water-related problems. The indigenous knowledge generated also gave the researchers valuable insights into the way the local people perceive their environment; this will be helpful in the research of other water related issues.

Acknowledgement

We acknowledge the assistance of the staff from BEED post graduate lab, who assisted in various data analyses.

Reference

Aitkin, S. C. (2002). Public participation, technological discourses and the scale of GIS. **In** Community participation and Geographic Information Systems, eds. W. J. Craig, T. M. Harris, and D. Weiner, 357-366. London: Taylor and Francis.

Baral. H 2004: Applications Of GIS in Community-Based Forest Management In Australia (And Nepal)thesis submitted for the degree of Master of Forest Science August 2004 School of Forest and Ecosystem Science Institute of Land and Food Resources The University of Melbourne.

Chambers, R. (1994). The origins and participatory rural appraisal, World Development, **22**: pp 1253-1268.

DAAD Alumni Summer School 2006. Participatory Watershed Management plan. FAO (1997) Participation in Practice: Lessons from FAO peoples Participation.

Programme, FAO. http://www.fao.org/sd/PPdirect/PPre0044.htm

Jarvis, K.A. and Stearman, A. M. (1995) Geomatics and Political Empowerment: The Yuqui. *Cultural Survival Quarterly*, **18**, 4, 58-61.

Kyem, P.A.K. (2006) Finding Common Ground in Land Use Conflicts Using PGIS. Lessons From Ghana. *Special Issue of PLA Notes,* **54**, pp 36-40.

Kyem, P. A. K. and Saku J. C. (2006). Web-Based GIS and the Future of Participatory GIS Applications Within Local And Indigenous Communities EJISDC (2009) **38**, 7, pp 1-16.

Nietschmann, B. (1995). Defending the Miskito Reefs with Maps and GPS: Mapping with Sail, Scuba, and Satellite. *Cultural Survival Quarterly,* **18**(4), pp 34-37.

Obermeyer, N. J. (1998). The evolution of public participation GIS. *Cartography and Geographic Information Systems*, **25**(2), pp 65-66. (Rambaldi and Callosa 2000).

Schoenhoff, D. M. (1993). The Barefoot Expert: The interface of Computerized Knowledge Systems and Indigenous Knowledge Systems. Westport, Greenwood Press.Devavaram, *et al.* 1991.

Ghose, R. (2001) Use of Information Technology for Community Empowerment: Transforming Geographic Information Systems into Community Information Systems. *Transactions in GIS,* **5**, 2, pp 141-163.

Laituri, M. (2002). Ensuring Access to GIS for Marginal Societies, **in**: Community Participation and Geographic Information Systems. Craig, J. W., Harris, T. M. and Weiner, D. (Eds.), New York, Taylor and Francis, pp 270-282.

Nietschmann, B. (1995) Defending the Miskito Reefs with Maps and GPS: Mapping with Sail, Scuba, and Satellite. *Cultural Survival Quarterly,* **18**, 4, pp 34-37.

Rambaldi, G. and Callosa, J. (2000). Manual on participatory 3-dimensional modeling for natural resource management. Essentials of Protected Area Management in the Philippines, Volume 7. Quezon

City, Philippines: National Integrated Protected Areas Programme (NIPAP), Protected Areas and Wildlife Bureau, Philippines Department of Environment and Natural Resources (PAWB-DENR).

Urban and Regional Information Systems Association (URISA), (2002). Proceedings of the 1st Annual PPGIS Conference, sponsored by Urban and Regional Information Systems Association, Rutgers University School of Planning and Public Safety, New Brunswick, New Jersey, July 21-23.

The Water Act 2002 No. *8* of 2002 http://faolex.fao.org/docs/pdf/ken37553-a.pdf Accessed on 1/10/10

Weiner, D., Warner, T. A., Harris, T. M., and Levin, R. M. (1995). Apartheid Representation in Digital Landscape: GIS, Remote Sensing and Local Knowledge in Kiepersol. Cartography and Geographic Information Systems.

CLOSING SPEECH

Vice-chancellor, Prof. Mabel Imbuga, deputy vice chancellors, Keynote speakers, paper presenters, conference participants, exhibitors, ladies and gentlemen.

I am greatly honoured to preside over the closing ceremony of the Fifth JKUAT Scientific, Technological and Industrialisation Conference that has been running for the last three days. After perusing through your presentations, I realize that they have covered many areas including advances and challenges in health sciences, engineering technologies and energy for production and infrastructure, Information and communication technology, public policy and governance, culture and socio-economic aspects of development, shelter and urban planning, agriculture, food security and value addition. These are areas that define our national development goals and objectives. I am also informed that the presentations elicited fruitful discussions and deliberations that are at the core of our development pillars as spelled out in vision 2030.

It is therefore gratifying for me to note that the conference would boost the activities of our national development agenda. Nevertheless a number of challenges have to be addressed to ensure that benefits accruing from the deliberations of this conference trickle down to the local community in the form of tangible projects. One such challenge is the translation of the conference output in the form of conference proceedings in to the said tangible projects for social economic development. The need for resource planning for this process to succeed cannot be overemphasized. Government involvement in terms of mobilization of resources through its various agencies is therefore critical.

As researchers you should always be at the forefront in agitating for more funding not only for research but also for extension activities. It is vital that you constantly interact and influence the industrial sector to avail more resources for research and its implementation. To this end, I want to thank the JKUAT for its impressive performance in research and extension activities. Despite the limited resources at their disposal, JKUAT has nevertheless made an impact in the area of technology transfer. I have in mind short courses that the university has been mounting that have gone a long way to empower our rural populations. One such training is in the area of mining and mineral processing where JKUAT has teamed up with the Taita Taveta mining community to offer them relevant skills designed to increase their technological capacity to exploit mineral resources as a commercial venture.

In addition JKUAT has also been running an in-country training programme targeting rural women groups drawn from all counties of the country who are trained in modern farming and agro-processing techniques. Similarly, the university together with the neighbouring Juja community has come up with a master plan to guide the development of Juja Township into a future university town. I would like to urge the private sector and other stakeholders to partner with JKUAT in this noble course.

JKUAT has within a short time of its history made a mark that has been felt not only in Kenya but also in the international arena. I have in mind one Mr Wadongo, a JKUAT electronic and computer engineering alumni who has developed the solar lamp that has attracted international attention and likely to revolutionalise the lives of the rural community in Kenya and even beyond the borders.

I am pleased to note that this conference has brought together over 140 participants drawn from various countries of the world. I am aware of the enormous resources you have committed in terms of planning, research and time that has seen the successful staging of this conference. I want to thank you very sincerely for your active participation.

It is important to note the JKUAT conference is a key annual event. I would like to take this opportunity to encourage you to continue to participate in subsequent conferences. I also thank all the stakeholders who have contributed in one way or another to the staging of this conference. To our international visitors, I wish to encourage you to spare a day or two to make a safari to some of our national tourist destinations to personally experience the unique Kenyan heritage.

It is now my pleasure to declare the fifth JKUAT conference officially closed.