IMPACT OF ENCLOSURES ON RANGE PRODUCTIVITY IN CHEPARERIA WEST POKOT COUNTY KENYA

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Impact of enclosures on range productivity in Chepareria West Pokot Kenya

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University

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DEDICATION

This work is dedicated to my brother Wilfred Kihara and my sisters Edith Njeri Rosemary Wanjiru and the entire family for your continued prayers and support. May God bless you all.

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LIST OF ABBREVIATIONS/ACRONYMS

NGO	Non Governmental Organisation
Me	milligram
PPM	Parts Per Million
GPS	Global Positioning System
Cmol	coulomb per mole
ANOVA	Analysis of Variance
Kg	Kilograms
Std.	Standard error
Sig.	Significance
Df	degrees of freedom
TEEB	The Economics of Ecosystems and Biodiversity
TOC	Total Organic Carbon
N tot	Total Nitrogen
P	Phosphorus
K	Potassium
Na	Sodium
Mn	Manganese
Fe	Iron
Ca	Calcium
Cu	Copper
Zn	Zinc
Mg	Magnesium
PH	Potential Hydrogen

ABSTRACT

In the semi-arid areas of West Pokot particularly Chepareria, majority of the people live semi sedentary lives while others are nomadic pastoralists. In the last three decades, there have been concerted efforts to restore and improve rangeland in this area. Use of enclosures, which is one of the key interventions, by the Vi Agro- forestry a Non-Governmental Organisation, enhancing with many ecological processes such as disturbance, is a method of rehabilitating degraded rangeland, which in turn affects vegetation dynamics. Adoption of these strategies by farmers has been gradual and some areas are still open and degraded. The aim of this study was to evaluate the effects of enclosures on range productivity in the semi-arid rangeland in West Pokot. Plant productivity, diversity and density were assessed in enclosures of different ages and in adjacent open land used for communal grazing. Questionnaires were also used to assess local community perception of the range restoration and improvement. Modified Whittaker plot was used for sampling in the selected enclosures and open areas. Herbaceous biomass and plant cover were greater in enclosures than in open areas. The average herbaceous cover in the enclosed area was 76% while that in the open it was 55% which was significantly different, $p<0.001$. The average herbaceous biomass in the enclosure was 137.2kg/ha while in the open it was 37.8kg/ha respectively. Enclosed areas are more productive than open areas and should be adopted in other dry areas as a method of rehabilitating degraded grazing lands.

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Overgrazing and deforestation continues to affect the productivity and genetic diversity of forests, woodland and grassland resources in dry lands areas. Exacerbated by recurrent droughts, the ultimate outcome of deforestation and degradation of these resources will be desertification, loss of livelihood and increased poverty (Mengistu *et al*., 2015). Sustainable conservation and utilization of the dry land vegetation resources and rehabilitation of those that have already been degraded provides economic, social and ecological benefits (Mengistu *et al*., 2005; Kaye-zwiebel & King, 2014).

In this regard, different strategies are used world over to improve and rehabilitate/degraded rangelands. For example, establishing enclosures has emerged as a promising practice in different parts of Ethiopia (Angassa & Oba, 2010; Mengistu *et al.,* 2015). It is a fast method triggering invasion, germination/sprouting, recruitment, establishment and growth of seedlings, modified underground stems or roots of indigenous species of grasses, herbaceous weeds, shrubs and trees that already exist at the spot either being dormant or suppressed by other plants or unfavourable environmental conditions. These propagules invade the area faster and with better coverage than planted seedlings. It is a cheap method since natural processes lead to regeneration of the vegetation without any human interference and financial investment (Mengistu *et al*., 2015).

In Kenya in the last three decades, there have been notable changes in vegetation in parts of West Pokot specifically Chepareria Ward (Triple L, 2013; Karmeback *et al*., 2015; Wairore *et al*., 2015). These changes can be attributed to many factors especially related to land use and management (Wairore *et al*., 2015). In West Pokot there have been efforts to improve range productivity and rehabilitate degraded areas. The key management interventions in this area include use of enclosures and afforestation (Makokha *et al.,* 1999). These efforts were differently accepted by individuals and hence notable local differences in general range health in the area. This study is part of a multidisciplinary research initiative that seeks to evaluate the impacts of these interventions on land, livestock and livelihoods (Triple L www.triplel.se) in West Pokot.

The broad goal of the Triple L is to understand the drivers of the changes in this ecosystem and their interrelationships. For example whether enclosures are leading to changes in land tenure from communal to private and the impact of these changes in social economics of the residents; whether improved livestock productivity can be attributed to enclosures and afforestation or changes in land tenure and what is the minimum land subdivision in this ecosystem; whether there is optimal size of enclosure and tree density for improved plant productivity and carrying capacity. This study seeks to understand the effects and mechanism behind the observed range improvement due to use of enclosures and afforestation.

1.2 Literature Review

Enclosures are areas closed off from grazing for a specific period of time with the aim of restoring degraded rangeland ecosystems (Mureithi *et al*., 2010). Since the objective of most enclosures is for range rehabilitation, they are usually established in degraded areas that have been used for grazing and crop production (Angassa & Oba, 2010). The practice of range enclosure has been traditionally exercised for a long time around church boundaries in Ethiopia by restricting the use of forests around churches as symbol of reverence for the religious sites(Mekuria & Yami 2013). Plant and animal diversity in enclosures increases with time after establishment (Mengistu *et al.,* 2005).

The use of traditional range enclosures locally known as kalo is widely practiced by pastoralists in East African rangelands (Angassa & Oba, 2010; Selemani *et al*., 2012; Mganga *et al*., 2015) mainly for dry season grazing. Traditional range enclosures have been useful in restoring heavily grazed rangelands by allowing the herbaceous vegetation diversity to recover (Angassa & Oba, 2010). Studies have shown that species diversity increases in enclosure with the age of enclosures than in continuously grazed open areas (Mengistu *et l.*, 2005; Angassa & Oba, 2010).

In southern Ethiopia, the use of traditional range enclosures is widely used by local herders as part of the conservation of pasture for young animals near settlement rangelands that are often heavily grazed and where forage for livestock is more scarce during the dry season (Angassa *et al.,* 2010). In the region where range scientists often have not been directly involved in land restoration, it might be worthwhile for local herders using their "traditional options" not only to serve as demonstrations in land rehabilitation but also use the "traditional management options" for ecological evaluations in terms of performance of rangeland production-inferred from biomass accumulation, changes in herbaceous plant species diversity and basal cover of grasses that would indicate the health conditions of individual plant species (Yami *et al*., 2007; Mganga *et al*., 2010; Mengistu *et al*., 2015).

Many studies have been done on role of enclosures on restoration and improvement of degraded or fragile ecosystems (Saffariha *et al.*, 2014; Park *et al*.,2015). (Mureithi & Opiyo, 2010) observed that in Kenya the impact of enclosures on ecosystem and socio-economic varies greatly with local conditions. He therefore, recommended a case by case consideration when implementing enclosures as range management strategy (Verdoodt *et al*., 2010). Other studies have looked at the reseeding as a range improvement and restoration strategy but mainly with grass species (Mureithi *et al.*, 2014). Enclosure establishment and active management has led to recovery of herbaceous vegetation, especially grasses and standing crop biomass, compared to the adjacent degraded rangeland in Lake Baringo (Mureithi *et al*., 2014).

The tangible benefits realized from the restored areas are one of the incentives driving rangeland enclosure establishment in the Lake Baringo basin (Mureithi *et al*., 2015). The improvement of the soil quality, general rangeland condition, and economic return show that creating rangeland enclosures is a potential avenue for combating land degradation and poverty in the dry lands where pastoralism is in transition from extensive to sedentary and hybrid systems (Shang *et al*., 2013). In Chepareria area there is more active vegetation management through enclosures, for production of fodder, crops and wood than in the neighbouring severely overgrazed open areas. Quantification of changes in vegetation and production is largely missing.

1.3 Problem statement

In Chepareria, a semi-arid region, low rainfall and its irregularity in space and time, leads to water scarcity and occurrence of long periods of drought. This has negative impacts on agricultural productivity and on water resources use for irrigation sector. The area lack appropriate technology and equipments for water harvesting, .Deforestation/ destruction of vegetation cover, water resource conflicts; poor planning, financial limitation, inappropriate land tenure, water pollution, insufficient irrigation water and perennial water shortage are the key strategic challenges affecting provision of water in Chepareria sub-county.

Frequent over grazing and increased population has led to a need for intensified and more productive land-use, including growing crops and trees. Increase in human and animal population, poor natural resource management and diminishing natural resource base, has led to severe land degradation, desertification and recurring conflicts which sometimes are fatal. The insufficient water and shortage of pastures, causes the pastoralists to fight for the common resources. This can lead to death of these pastoralists or cattle rustling.

1.4 Justification

Vegetation plays an important role of protecting the soil surface from rain drop splashing, increasing soil organic matter, soil aggregate stability, water holding capacity, retarding and reducing surface water runoff, etc. Measuring vegetation cover, frequency, biomass and density in the open areas and areas in enclosures helps to account for the changes in the area. In West Pokot County, especially in Chepareria, changes in livestock grazing patterns due to insecurity, population pressure and drought have led to concentration of people and livestock in the safe areas leading to a serious reduction in vegetation. Previously in Chepareria, pastoralists were nomadic, moving with their livestock from one place to another and the land was owned communally. In addition the high population growth rate in the dry lands lowers food production leading to food insecurity. Pastoralists in Chepareria have a more settled lifestyle, since the introduction of enclosures, there are more pastures.

The increasing trends in land degradation threaten the survival of biodiversity including agro-biodiversity. Extinction of rare, threatened and endemic species has occurred in some dry areas. Most of the land in dry lands or pastoral areas is under the communal land tenure system where the "tragedy of the commons" may apply since no one feels responsible to protect land or resources he does not own. There is no incentive to conserve the land and most of it is exposed to erosion.

The plants that grow in this rangeland, in places that are not degraded, not only provide feed to livestock and wildlife, but also hold the soil in place, increase water infiltration and promote availability of soil minerals. The health and productivity of the rangeland ultimately depends on the condition of the soil surface. Measuring the vegetation cover, biomass, frequency and density, is a useful tool for measuring the condition of the soil surface and the health of the rangeland. Thus there is need to quantify the vegetation parameters in the area in order to know the health and productivity of the area. The data obtained is helpful since it will be used to raise awareness about the importance of sustainable land management and therefore promote action that will protect the dry lands.

1.5 Hypothesis

Enclosures have no impact on rangeland plants productivity

1.6 Objectives

1.6.1 General objective

To determine the impact of enclosures on range land productivity in Chepareria, West Pokot, Kenya.

1.6.2 Specific objectives

1. To determine the impact of enclosures on plant cover, biomass, frequency and tree density within enclosures and in the adjacent open areas of Chepareria, West Pokot.

2. To evaluate the indigenous knowledge, on range monitoring and rehabilitation in Chepareria, West Pokot.
3. To determine the effect of enclosure on soil seed bank and soil nutrients in Chepareria, West Pokot.

CHAPTER TWO

MATERIALS AND METHODS

2.1 Study site

The research was carried out in Chepareria West Pokot where the climate is semi-arid. The population of Chepareria is 41,563 people who comprise mainly the Pokot (KNBS 2009). In West Pokot County (Kenya), changes in livestock grazing patterns – due to insecurity, population pressure and drought – have led to a serious reduction in vegetation. Large areas once well covered with pasture and trees have become entirely denuded, eroded. In West Pokot County, Kenya, over-grazing on common pastures had generated serious depletion of soils and left the ground bare and erodible (Svanlund & Nyberg, 2014).

In 1986 the Swedish non-governmental organization (NGO) Vi- Agroforestry, started a rehabilitation program for groups of farmers around Chepareria, designed to reduce the intensity of grazing and improve livelihoods (Makokha *et al*., 1999; Svanlund & Nyberg, 2014). Usage of live-fences to control the density of livestock, and promotes rotational grazing as sustainable management practice was encouraged. This improved infiltrability and water holding capacity, erosion control and improved soil fertility, as well as future possibilities of carbon sequestration and compensation (Svanlund & Nyberg, 2014). The interest among farmers has increased substantially, from only a few dedicated participants, to most of the farmers in the area. Most farmers/cattle owners adopted, and continue to adopt and adapt, the methodologies (Svanlund & Nyberg, 2014; Wairore *et al*., 2015).

Rainfall is bimodal with the long rains falling between March and June while the short rains occur between September and November. The rainfall amounts range from 150mm-400 mm. The area receives an average annual rainfall of about 270mm (Svanlund & Nyberg, 2014). Temperatures in the lowlands range from15^{o}C to 30^{o}C but the highlands may experience temperatures as low as 9^{o}C. The major drainage systems in the sub-county are Turkwel, Kerio and Nzoia Rivers. Both the Turkwel and Kerio Rivers drain northwards into Lake Turkana while Nzoia River drains into the Lake Victoria in the south. Vegetation types include moist forest, dry woodland, bush land, and desert scrub-tree species (Wairore *et al.,* 2015). The soils, derived primarily from metamorphic rocks of the Precambrian basement system, are shallow, rocky, and prone to erosion in some areas; deep, fertile, and well drained in others (Wairore *et al*., 2015). The highland areas are covered by forests, but deforestation owing to population pressure outpaces the designation of forest reserves; to increase forest cover, which is critical to water retention, the government operates a number of tree nurseries in West Pokot (Svanlund & Nyberg, 2014; Wairore *et al*., 2015).

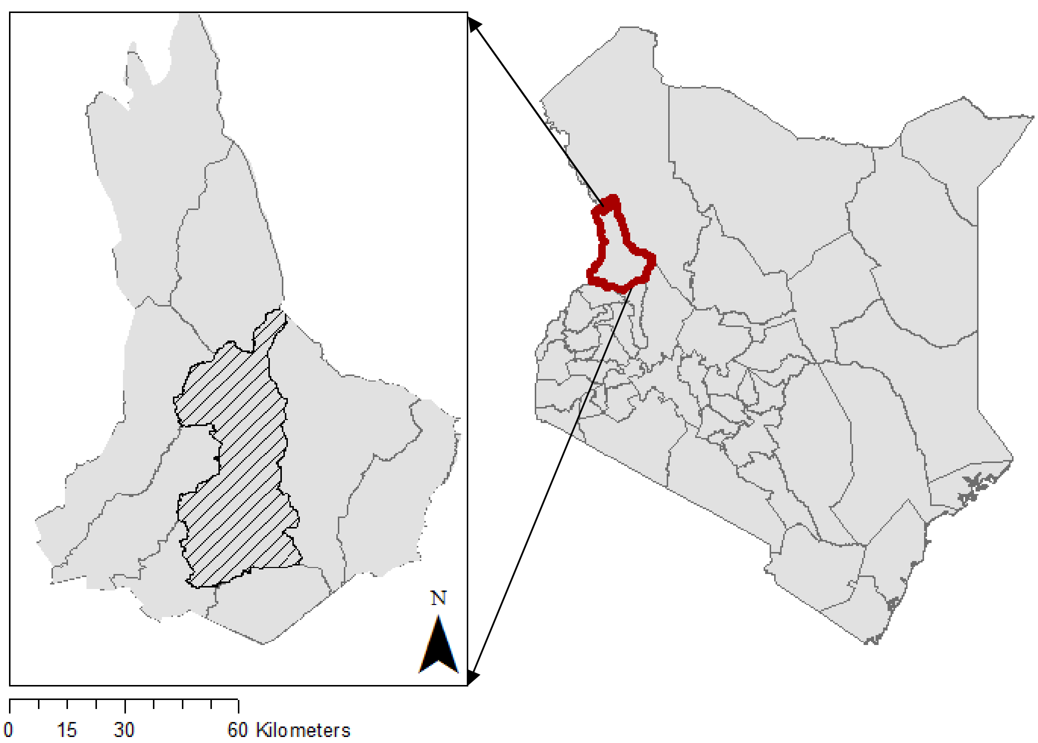

Figure 2.1: Study site in Chepareria in West Pokot in Kenya

(County Government of West Pokot, 2013)

2.2 Sampling method

Purposeful sampling was carried out only in the areas where enclosures have been adopted and the adjacent open areas in Chepareria in West Pokot. The selection criteria used was based on similarity of terrain, based on different ages of enclosures and checking the terrain of the land, the plot was laid along any notable environmental gradient such as slope or soil type in order to cover the most variation possible and land use. The field assistant was highly involved in the establishment of the enclosures, so he was well informed about the ages of the enclosures. The age of enclosures was sourced from farmers who enclosed their land years later after the Vi Agroforestry exit.

The modified Whittaker plot (Stohlgren, 1997), was used for data collection. Once a site had been selected, a stone was thrown and the side it falls was the starting point. GPS coordinates were taken to document the location of the sampling sites. Four age classes of enclosures were sampled; enclosures which are 1-5 years, 6-10 years, 11-15 years and over fifteen years. Adjacent unprotected areas to the respective enclosures were also included in the study. The field assistant was there during the introduction and implementation of the enclosures. This, together with the farmers' knowledge on the implementation of the enclosures gave the age of enclosures.

2.3 Vegetation data

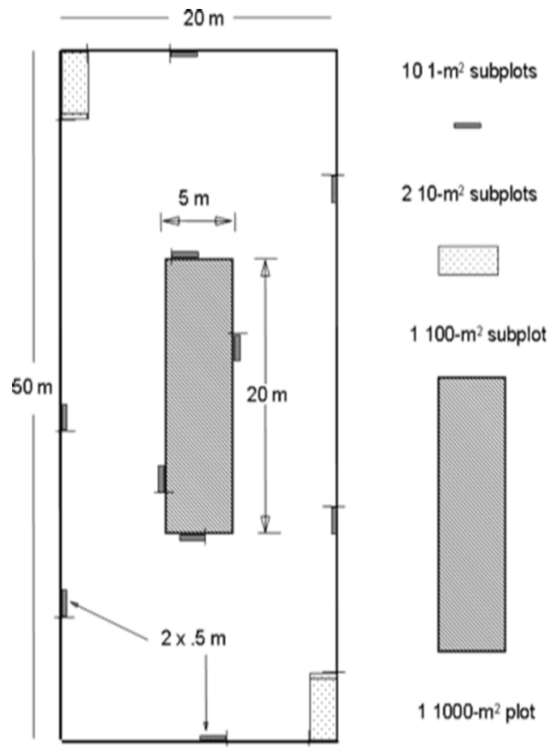

Figure 2.2: A modified Whittaker plot

2.3.1 Plant cover

Twenty one sites within enclosures and comparable twenty one sites in the open areas were sampled. Efforts were made to sample enclosures of different ages in order to assess the effect of age of enclosure on range health. Vegetation cover was measured in the field by assessing the percentage of the ground that is covered by the existing annual or perennial vegetation (Park *et al*., 2015). In the ten $1m^2$ quadrat, percentage covers of all herbaceous plant species were recorded. The $1m^2$ quadrat was divided into 100 equal squares, by measuring and putting nails at equal distance and the squares occupied by the square counted. Bare ground, rock, litter (i.e., detached dead plant material), duff (i.e., attached dead plant material), water, and dung were also recorded.

2.3.2 Biomass

Herbaceous biomass was harvested in one of the ten $1m^2$ subplots in the modified Whittaker plot, where random numbers were assigned to the 10 subplots and the three picked from them. Herbaceous material was harvested and weighed in the field and a sub sample taken and fresh weight taken. The subsample was dried in the laboratory for dry biomass (Cornelissen *et al*., 2003; Angassa & Oba, 2010; Mureithi *et al*., 2014; Mengistu *et al.,* 2015).

2.3.3 Frequency

Frequency of each species in the modified Whittaker plot was recorded in order to determine species composition and density. Frequency of trees and shrubs species was assessed in the two$10m^2$, one 100 $m^2$and one $1000m^2$ areas. Only species present within the bounds of the sample quadrat was recorded, with no regard to size or number of individuals. Plant frequency was determined as a function of quadrat size and reflects both plant density and dispersion. The sensitivity of frequency data to density and dispersion make frequency a useful parameter for monitoring and documenting changes in plant communities (Cornelissen *et al.,* 2003; Kigomo & Muturi, 2013; Kasim *et al.,* 2015).

2.3.4 Density

Trees and shrubs within the laid modified Whittaker plot (for the 20m by 50m), were counted, identified and recorded (Cornelissen *et al.,* 2003; Mekuria & Yami 2013; Zhan *et al*., 2013; Kasim *et al*., 2015).

2.4 Seed bank analysis

Seed bank sampling and soil nutrient analysis was carried out, where 10 soil cores of 4cm diameter to a depth of 10cm within each of the ten $1m^2$ sub plots of the modified Whittaker plot, were taken put in a bucket and mixed thoroughly and a sub sample taken for analysis. The samples were washed over a sieve after mixing them together. The samples with the seeds were put in trays and placed in a greenhouse for germination. Seedling were identified, counted and removed immediately (Horneck *et al*., 2011; Bekker *et al*., 2016).

2.5 Assessment of range condition

Knowledgeable herders (key informants like elders, chiefs) were selected based on age and experience and interviews on broad issues related to indigenous range resource management techniques were conducted (Wairore *et al*., 2015). A semi structured questionnaire was used to establish prevailing traditional techniques to assess and monitor range condition and probable mitigation measures taken if the status of the range resource was undesirable (Oba, 2009; Abate *et al*., 2010; Shiferaw *et al*., 2013). Hundred households were selected in the areas where the use of enclosures has been employed and a few that haven't employed the method. These helped to get information from people who have lived in the area for over thirty years in terms of the environmental history of grazing landscapes and their perception of quality change.

The key informants were interviewed and asked to describe: the factors or indicators they use to evaluate suitability of a particular range for livestock grazing; the methods they apply to rate the condition of the range and what measures they take when the condition of particular range was deemed too poor for grazing.

2.6 Data Analysis

Data collected were analysed using excel. Data on indigenous knowledge was coded and then computed and analysed. T-test was used to compare and analyse vegetation in enclosures and those in the open areas. Correlation was also used to correlate cover with other quantitative measures like biomass. Data were presented in graphs, pie charts and tables.

CHAPTER THREE

IMPACT OF ENCLOSURES ON RESTORATION OF A SEMI-ARID RANGELAND IN WEST POKOT COUNTY, KENYA

3.1 Introduction

Overgrazing and poor land management are the most common causes of desertification and biodiversity loss in rangelands (Li *et al.*, 2009; Zhang *et al.,* 2012). This is exacerbated by recurrent droughts with ultimate outcome of deforestation and degradation of these resources resulting in loss of livelihood and increased poverty. Sustainable conservation and utilization of the dry land vegetation resources and rehabilitation of degraded areas provides economic, social and ecological benefits (Beyene, 2010; Shang *et al.*, 2013). In this regard, different strategies are used to improve and rehabilitate degraded rangelands. For instance, establishing enclosures has emerged as a promising practice in different parts of East Africa such as northern Kenya and southern Ethiopia, China and India (Li *et al.*, 2009; Mureithi *et al.*, 2010; Angassa & Oba, 2010; Zhang *et al.*, 2010).

In some of these areas it has been a successful way of rehabilitating degraded rangeland while in others it has not succeeded since the locals have not been involved in the establishment and maintenance of the enclosures (Angassa &Oba, 2010). Mureithi and Opiyo (2010) observed that in Kenya the impact of enclosures on ecosystem and socio-economic varies greatly with local conditions. They therefore, recommended a case by case consideration when implementing enclosures as range management strategy. Other studies have looked at the reseeding as a range improvement and restoration strategy but mainly with grass species (Mureithi *et al.*, 2014). Enclosure establishment and active management has led to recovery of herbaceous vegetation, especially grasses and standing crop biomass, compared to the adjacent degraded rangeland like in Lake Baringo (Mureithi *et al.*, 2014). The tangible benefits realized from the restored areas are one of the incentives driving rangeland enclosure establishment in the Lake

Baringo basin (Mureithi *et al*., 2015). The improvement of the soil quality, general rangeland condition, and economic return show that creating rangeland enclosures is a potential avenue for combating land degradation and poverty in the dry lands where Pastoralism is in transition from extensive to sedentary and hybrid systems (Wasonga *et al*., 2003; Karmebäck *et al*., 2015).

Rangelands are restorable natural resources with different uses such as providing the main part of livestock forage. In some parts of the world like Shinyanga in Tanzania, the Sukuma people, enclosures of the Acacia-Miombo woodland, are used for the dry season fodder, firewood and other essential products. However, by around 1985 these enclosures had been abandoned and deforestation was on the rise and the area had been degraded (Barrow & Mlenge, 2003; Barrow & Shah, 2011). Later the government together with the input of the community rehabilitated the area within a short period of time by excluding the livestock to hasten restoration.

In southern Ethiopia, the use of traditional range enclosures is widely used by local herders as part of the conservation of pasture for young animals near settlement rangelands that are often heavily grazed and where forage for livestock is more scarce during the dry season (Angassa & Oba, 2010). In the regions where range scientists often have not directly involved the locals, in land restoration, it might be worthwhile for local herders using their "traditional options" not only to serve as demonstrations in land rehabilitation but also for ecological evaluations in terms of performance of rangeland production-inferred from biomass accumulation, changes in herbaceous plant species diversity and basal cover of grasses that would indicate the health conditions of individual plant species (Angassa & Oba, 2010)

Enclosures are areas selected for natural regeneration of the native flora as a means of land restoration through protection of the areas from human and animal interference (Verdoodt *et al*., 2010). Since the objective of most enclosures is for site rehabilitation they are usually established in eroded and degraded areas that have been used for grazing and crop production in the past. The practice of enclosure has been traditionally exercised for centuries around church boundaries in Ethiopia by restricting the use of forests around churches as prestige for the religious sites.

Plant and animal diversity in enclosures increases with time after establishment (Mengistu *et al*., 2005). Traditional grazing deferment has been widely practiced by pastoralists in East African rangelands (Angassa & Oba, 2010) in the past. Pressure on land from the increasing human population in the last century has reduced this practice resulting into rampant degradation in east African rangelands. Enclosing portions of the rangeland was identified as the alternative method of ensuring deferment and hence restoring heavily grazed rangelands by allowing the herbaceous vegetation diversity to recover (Verdoodt *et al*., 2010).

Over the last three decades, in Kenya, there has been notable transformation in land cover in parts of West Pokot in Kenya especially in Chepareria Sub-County (Nyberg *et al*., 2015). These changes can be attributed to many factors especially related to land use and management. In West Pokot there have been efforts to improve range productivity and rehabilitate and afforest degraded areas using enclosures over the last three decades. The adoption of these interventions differed, where some people adopted the use of enclosures while others did not, hence the notable local differences in the general rangeland condition in the region. This study is part of a multidisciplinary research that seeks to evaluate the impacts of these interventions on land, livestock and livelihood in West Pokot.

West Pokot is one of the areas which was highly eroded and degraded before Vi Agro foresting, a Non-Governmental Organization (NGO), introduced the enclosures in the area as a way of restoring the degraded area in 1985. Chepareria ward was formerly an area that was communally owned, but later there was demarcation and land subdivision in the area, where majority of people own land individually. In the area studied, there is more active vegetation management through enclosures for production of fodder, crops and wood than in the adjacent severely overgrazed open areas. The aim of this study was to examine the impacts of enclosures on vegetation productivity and provide scientific information for the restoration of formerly degraded semi-arid rangelands of Chepareria, West Pokot Kenya.

3.2 Materials and method

The study was conducted in the months of November to January 2014-2015.The sampling was done in November after the short rains. Four age classes of enclosures were sampled; enclosures which are over fifteen years (>15 years old), 11-15 years, 6-10 years and 1-5 years old. Open rangeland were also sampled to find out the differences in land cover with the enclosures. Sampling was carried out only in the enclosures and in the adjacent open areas in Chepareria in West Pokot using the Modified Whittaker Plot (Stohlgren, 1997).

The modified Whittaker plot was laid along notable environmental gradient such as slope or soil type .The starting point was randomly chosen and the GPS coordinates of the sampling sites taken. Twenty one sites within enclosures of different ages and under agro-forestry and comparable twenty one sites in the open areas were sampled. Vegetation cover was measured in the field by assessing the percentage of the ground that is covered by the existing annual or perennial vegetation. The Modified Whittaker Plot was used to sample vegetation cover, in the ten $1m^2$ subplots; per cent covers of all herbaceous plant species were recorded. The $1m^2$ quadrat was subdivided into a hundred squares and each square represented a percentage and the ones occupied by the plants were counted to represent the percentage. Bare ground, rock, litter (i.e., detached dead plant material), duff (i.e., attached dead plant material), water, and dung were also recorded. This was repeated in the two $10m^2$, one $100m^2$and one $1000m^2$.

Herbaceous biomass was harvested in the ten $1m^2$ subplots in the modified Whittaker plot, random numbers were assigned to the 10 subplots and the one picked from them. Herbaceous biomass was harvested in one of the $1m^2$ quadrat using a $0.25m^2$quadrat; the herbaceous crops were clipped at 2cm above the ground level, oven dried for 48 hours to a constant weight at 70°C to obtain the dry biomass.

Frequency of each species in the modified Whittaker plot was recorded in order to determine species composition and density. Frequency of trees and shrubs were also recorded in the ten $1m^2$ subplots. Frequency of species was assessed in the two$10m^2$, one 100 $m^2$and one $1000m^2$ areas. Only species present within the quadrat was recorded, with no regard to size or number of individuals. Plant frequency is a function of quadrat size and reflects both plant density and dispersion. Tree density and shrubs within the laid modified Whittaker plot were counted, identified and recorded (Cornelissen *et al*., 2003).

3.3 Results

The comparison made between enclosures and adjacent open grazing lands showed that productivity was higher in the enclosures.

3.3.1 Trees density

Enclosures had significantly influenced the average number of trees in Chepareria rangeland (t_{40}= 0.048, P< 0.01). The number of trees increased with the age of the enclosure. 55% of the increase in number of trees is due to the introduction of enclosures. There are a few cases where the number of trees within the enclosures was less. In one of the enclosures between 1-5 years old, it had an average of 60 trees/ha which was lower than in the open areas. There are other instances, in the other classes of enclosures when the average number of trees was less.

In one of the enclosures of the class 6-10 year old enclosure, there was an average of 190 trees; 11-15 years old enclosure had some with as low as 240 number of trees on average and >15 years , one of the enclosures had 270 number of trees ha^{-1} on average.

The average number of trees per hectare in the enclosed areas was more than in the open areas, (Figure 3.1).

Figure 3.1: Average number of tree ha -1 at different ages of enclosures Chepareria, West Pokot Kenya.

3.3.2 Tree Species richness

Enclosures had more tree species richness than open areas (t_{40}=2.045 P=0.03). Species richness (the number of species) increased significantly with increasing years of protection from grazing .The average number of trees in Chepareria was lowest in the open areas and in the 11-15 years old enclosures. In the 1-5, 6-10 and over 15 years old enclosures, the average number of trees increased with enclosure age respectively.

Species richness increased with increase in age of enclosures (Figure 3.2)

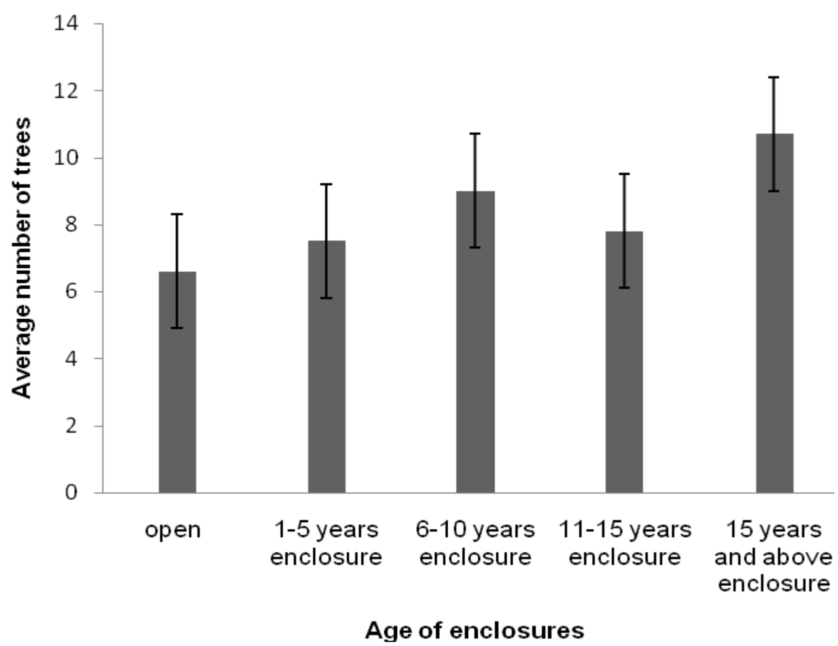

Figure 3.2: Species richness under different ages of enclosure Chepareria, West Pokot Kenya.

3.3.3 Biomass

Open areas had significantly lower biomass than enclosed areas (t_{40}=4.413P<0.001) (Figure 3.3). The average biomass in enclosed areas was higher compared to open areas. In the open (0 enclosure) average biomass was 37.7, while in the enclosures it was 86.4 in the 1-5 years old, 185.9 in 6-10 years old, 111 in 10-15 years old and 159.2 in the >15 years old respectively in different classes.

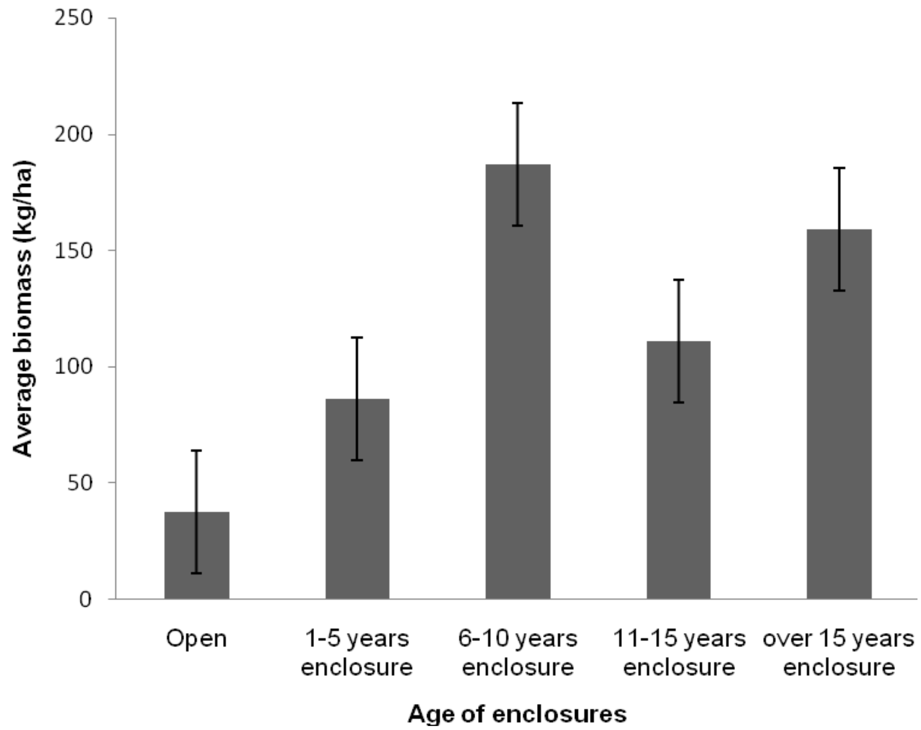

Figure 3.3: Average biomass under different styles management, Chepareria, West Pokot Kenya

Biomass increased with enclosure age and was low in the open areas (Figure 3.4). There are a few cases where middle aged enclosures had more biomass than some older enclosure. In the open areas and enclosures of 1-5 years old, the herbaceous biomass was low. Biomass increased with the age of enclosure. About 64 % increase in biomass is accounted for by the enclosures.

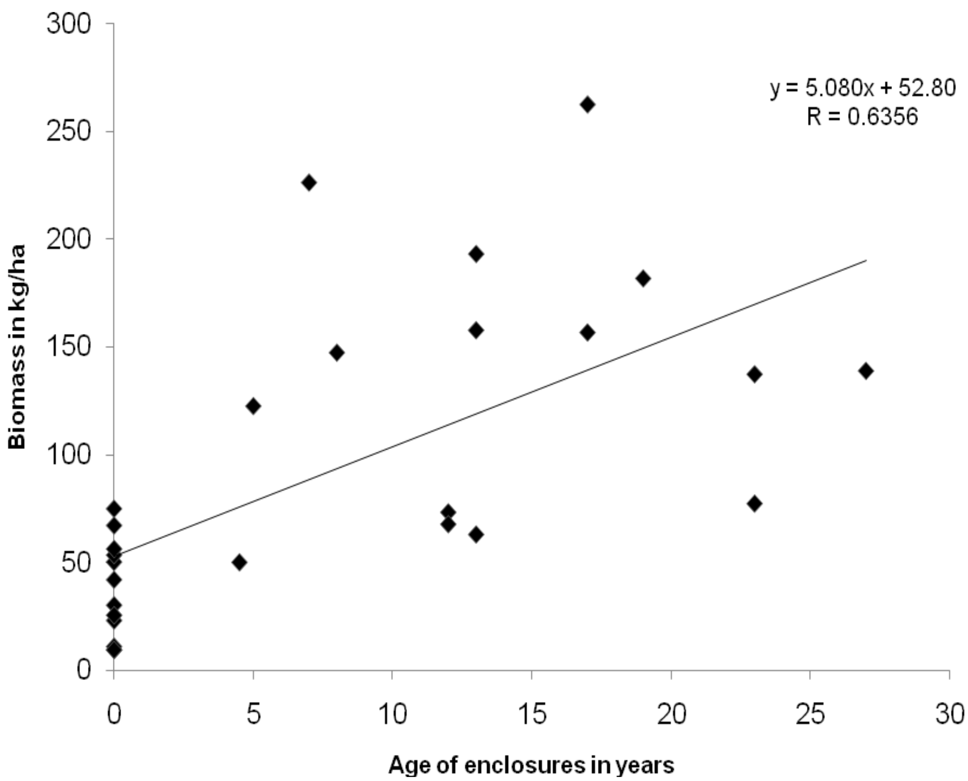

Figure 3.4: Variation of biomass in (kg ha-1) with enclosures age in Chepareria, West Pokot Kenya

3.3.4 Herbaceous plant Cover

The open grazing area had a significantly low mean herbaceous cover compared to the enclosed areas (t_{40}=4.043, P<0.001). Herbaceous plant cover increased with enclosures age. In the open areas average herbaceous plant cover was 55% while in the enclosures it was,70 in the 1-5 year old enclosures, 73% in 6-10 year old enclosures,76% in 11-15 year old enclosures and 79% in the over 15 year old enclosures (Figure 3.5)

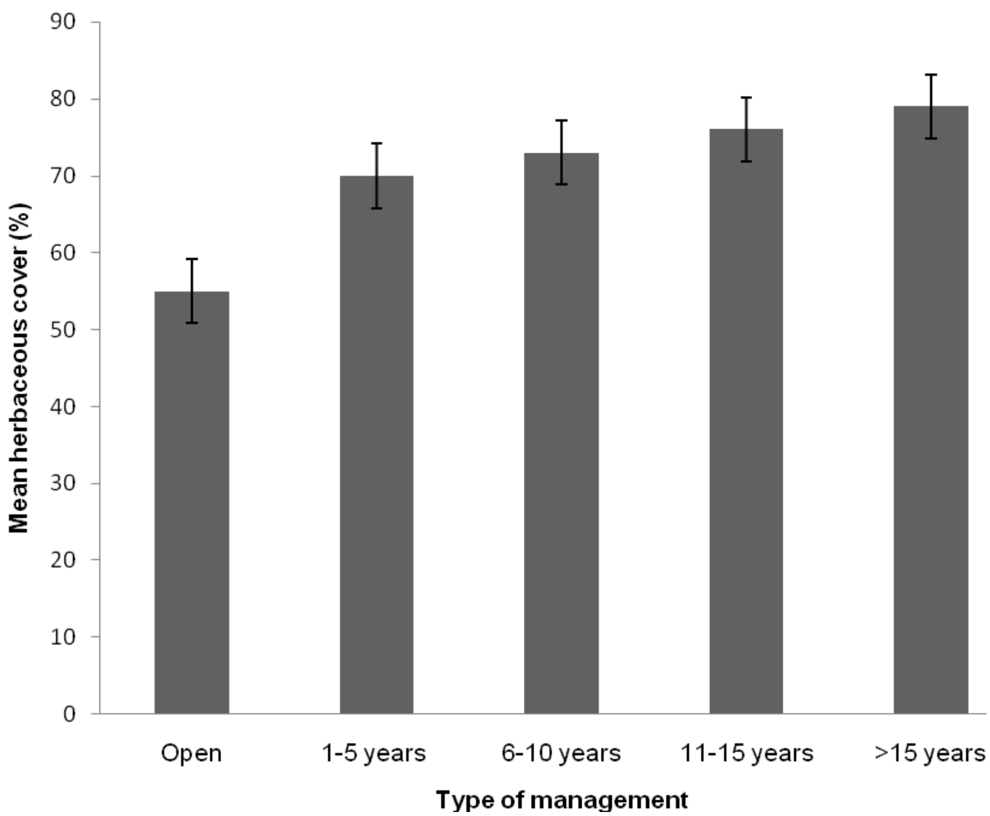

Figure 3.5: Variation in herbaceous cover (%) with enclosure age in Chepareria, West Pokot Kenya

On average enclosures have more herbaceous plant cover (76%) than open areas (55%) (Figure 3.6)

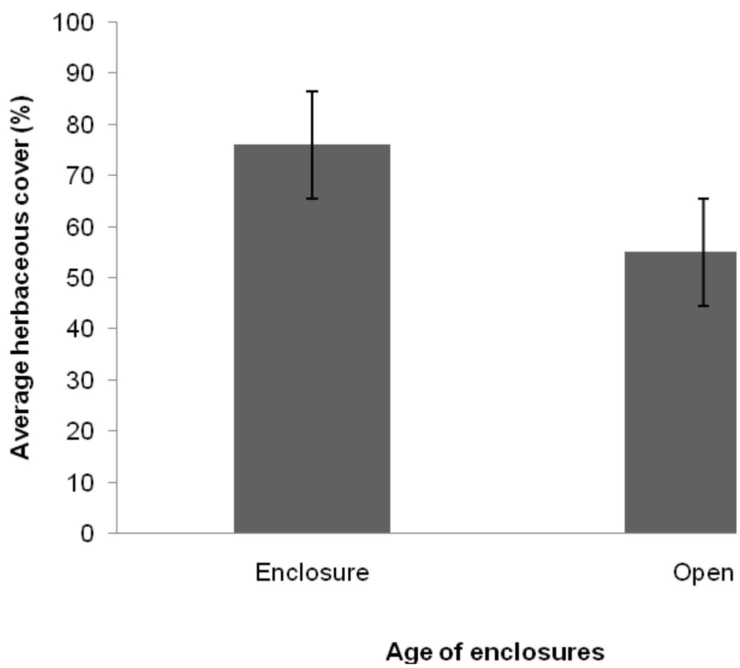

Figure 3.6: Average per cent herbaceous cover in enclosures and adjacent open areas in Chepareria, West Pokot Kenya

When herbaceous cover is compared with biomass, there is a strong correlation such that an increase in herbaceous cover also leads to an increase in biomass, with enclosure (Figure 3.7). Therefore, cover can be used as a predictor of biomass, since assessment of biomass is through destructive measures.

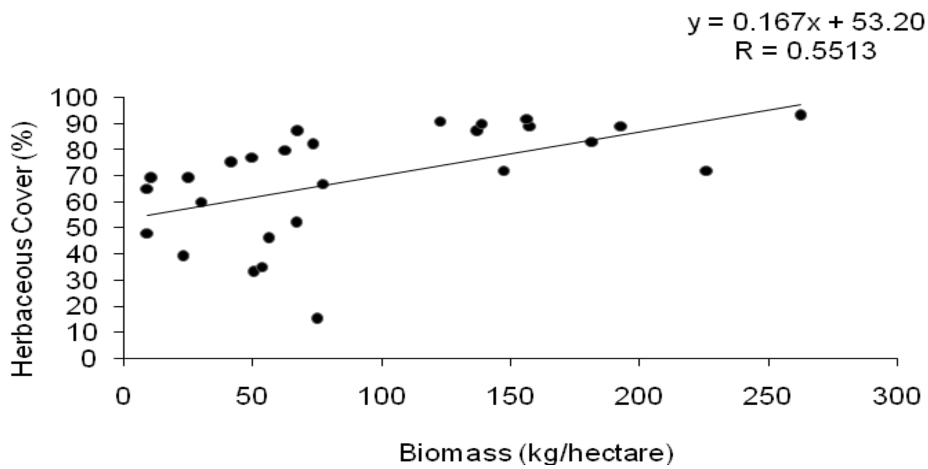

Figure 3.7: A comparison between herbaceous cover and biomass in Chepareria, West Pokot Kenya

3.4 Discussion

The assumption of the present indicates that the paired sites were comparable and differences in native plant species richness, diversity and aboveground standing biomass measured between the paired enclosures and adjacent communal grazing lands were mainly caused by land-use change (that is, enclosure establishment) and not by inherent site variability. The results of the present study demonstrated the importance of enclosures in the restoration of degraded arid land.

From the study it was evident that enclosures have higher density of trees than the open areas. This can be attributed to the management the enclosure owners apply. Similar studies in Ethiopia by Mekuria *et al.*, (2006) also showed that woody species are higher in enclosures than adjacent open areas. The sensitivity of frequency data to density and dispersion make frequency a useful parameter for monitoring and documenting changes in plant communities. In terms of age difference, the older enclosures had higher density of woody species than younger enclosures. The younger enclosures with higher tree density; have younger trees such as the Acacia Spp which have germinated and forms thicket in those enclosures.

Trees and shrubs are valuable resources in grazing lands and complement the grasses as sources of livestock fodder and browse. Trees have multiple uses such as: shade both for human and livestock, wood for construction, fuel wood and charcoal, leaves as vegetable for human consumption, animal fodder, litter for soil fertility improvement, flowers provide nectar for bees, forage, medicinal value, cultural conservation, deep tree roots extract nutrients from deep soils to the upper soils, scenery and landscape beauty (Makokha *et al*., 1999).

Herbaceous biomass was lower in the open areas than within the enclosed areas. The older enclosures had more biomass. From the study, higher biomass within the middle aged enclosures can be attributed to management and protection of the enclosed areas. Establishment of enclosures enhanced the total herbaceous biomass compared to plots not enclosed. Open areas have lower biomass which can be attributed to continuous grazing by many livestock throughout the year. In the open, there is nobody to take care of the fields since the land is owned communally and the free for all open access exacerbates degradation. These results are similar with some research done in Ethiopia where herbaceous biomass was significantly high in enclosures than in open grazed areas (Angassa *et al*., 2010). Park *et al*., 2015 also observed that aboveground biomass increased with increase in age of the enclosures.

From the results, it is evident that herbaceous plant cover increases with increase in years of enclosure. The higher herbaceous plant cover in all enclosures compared to adjacent open areas illustrates that rehabilitation of degraded grazing lands occur within a short period of time after restricting human and livestock interference.

This has also been proved by Mekuria and Yami (2013) in Ethiopia, where herbaceous cover has also been high in enclosures than open areas. However, Mengistu observed that herbaceous plant cover and tree species richness varied between enclosures and open areas (Mengistu *et al.,* 2005).

These results are similar to what Mekuria and Yami (2013) observed in Ethiopia, where above ground herbaceous biomass, plant species richness, herbaceous plant cover and woody species (trees) were higher in enclosures than adjacent open communal land. Studies in Ethiopia have also shown that enclosures provide a microhabitat for plants which are effective method to improve above ground vegetation (Mengistu *et al*., 2005; Abebe *et al*., 2006; Yami *et al*., 2006).

Most of the palatable (to livestock) woody plants especially *Balanites aegyptiaca* are on the increase inside the protected area and they are also used as vegetables by the Pokot. B. *aegyptiaca* is a hardy tree that is green throughout the year and thus providing pasture and food during the dry season, when other plants had dried up. Enclosures are highly managed by the owners because of the benefits they get while open areas are grazed upon by anybody and there are no incentives to care for it. The comparison made between the enclosures and open grazing land showed that the composition and diversity of vegetation were higher in the enclosures, suggesting rehabilitation of degraded land by avoiding or minimizing interference of people and domestic animals in the degraded lands with establishing enclosure measures.

Some enclosures are invaded by weeds especially *Lantana camara and Solanum incanum*. *L. Camara* is an invasive species with allelopathic impacts hindering the growth of other plants in the surrounding causing bush encroachment and hindering grazing. This suggests that enclosures require management. In some areas, farmers uprooted the *S. incanum* (Sodom apple) and *Lantana camara* since they are not palatable to livestock and exposed them to the sun to be scorched and be dried. This way they are able to control them. In the open communal land, no one takes care or responsibility leading the proliferation of weeds and invasive species.

3.5 Conclusion

Enclosed areas in Chepareria, West Pokot Kenya are more productive as they had more herbaceous plant cover, herbaceous biomass, high tree density and higher species richness compared to adjacent open areas. The more years one encloses his land the more the productivity. Plants are useful as source of livestock feed and human beings. The availability of pastures, due to enclosures, has enabled the residents of Chepareria to settle down and ensures they have pastures throughout the year.

CHAPTER FOUR

INDIGENOUS KNOWLEDGE ON RANGE MONITORING AND REHABILITATION: PASTORALISTS' PERCEPTION ON USE OF ENCLOSURES IN CHEPARERIA WEST POKOT KENYA

4.1 Introduction

Indigenous knowledge is the systematic body of knowledge acquired by local people through accumulation of informal experiences and intensive understanding of their environment in a given society (Cheserek, 2005). Phenological knowledge held in the indigenous communities has a high value. Many traditional societies have built up knowledge over long periods about environmental change and have developed elaborate strategies to recognize and cope with this changes e.g. floods, droughts, disease and pest infestation and their attendant effects (Egeru, 2012).

Pastoralists' knowledge of the fragile eco-system is reflected clearly in their adaptation strategies to the dry lands. Pastoralists adopted several techniques to secure their livelihood in an unpredictable environment. The most efficient strategies include herd mobility, flexible stocking densities, and diversification in animal species, as well as in income generation activities (Abdalla *et al.,* 2012; Kaye-zwiebel & King, 2014). For hundreds or thousands of years pastoral communities across Africa such as Masaai, Gabbra, in Kenya; Borana, Oromo and Afar in Ethiopia; Berber in North Africa; Fulani or Fulbe in west Africa; Beja, Shukriya and Rashida in the eastern Sudan have adopted mobility as highly efficient strategy to cope with scarcity of re-sources in dry lands of African Sahel.

Availability of pasture and water are the essential factors behind the determinant of time and direction of their movement. They move to the north during rainy season and to the south during dry season. Irregular movements out of these cycles occur in case of conflict and disease outbreaks (Abdalla *et al.*, 2012; Angassa, 2012). Indigenous knowledge is stored in the memories of community elders and is passed on to younger generations verbally or through education techniques exercised during rites of passage (circumcision), in ceremonies and rituals and social interactions between group members (Barrow & Mlenge, 2003; Cheserek, 2005; Dabasso *et al.*, 2012). It also refers to the unwritten collective experiences acquired by a particular community for hundreds or thousands of years used for securing their livelihood.

Pastoral communities usually have a detailed knowledge of their grazing lands, acquired through extensive observation, handed down from one generation to the other generations and continuous herding practices (Abate *et al.*, 2010). Documenting indigenous knowledge of rangeland can provide useful information for the development, sustainable utilization and conservation of natural resources (Abate *et al*., 2010). Moreover community-based knowledge may provide new insights for improving existing scientific knowledge and a basis for designing appropriate research and development policies.

Pastoralists have managed their production system for many centuries and have had detailed knowledge of the biodiversity and environment of their grazing lands. Despite the existence of such valuable knowledge, researchers and development experts have previously deliberately overlooked the indigenous knowledge in the evaluation of rangeland. A combination of pastoral indigenous knowledge and modern scientific information would be helpful in providing a better understanding of the environment from the perspective of those utilizing the resources. Feeding of livestock is still a major challenge to sustainable productivity of pastoral communities in the dry land areas (Oba, 2009; Riginos & Herrick, 2010; Abdalla *et al*., 2012). Local communities have accumulated important knowledge on rangeland monitoring and assessment which are associated with local strategies to sustain livelihood systems (Roba, 2008; Abate *et al*., 2010; Abate, 2016).

Local vegetation is monitored for changes in plant species composition that may affect key fodder species for livestock grazing. Since livestock is the main source of livelihood for most pastoralists, herders perception of land degradation are influenced by livestock production requirements (Roba, 2008). Herders not only monitor the trends of vegetation change over the long term but they also make inferences from livestock production performances (Angassa, 2012; Huho, 2012). In terms of vegetation, herders monitor both the quality and quantity of fodder. The status of vegetation guides herder's decisions for livestock management. Herders in many areas use abundance of palatable species as indicators for assessing range condition (Kioko & Okello, 2010; Mganga *et al*., 2010; Angassa, 2012; Kaye-zwiebel & King, 2014).

4.2 Material and methods

One hundred households of herders were selected in the areas where the use of enclosures has been adopted and a few that have not adopted the method. Men and women who were over thirty years were selected as this would help get information from people who have lived in the area for over thirty years in terms of the environmental history of grazing landscapes and their perception of quality change.

Structured questionnaires were used to establish prevailing traditional techniques to assess and monitor range condition and probable mitigation measures taken if the status of the range resource is undesirable (Angassa & Roba, 2008; Mganga *et al*., 2010; Kaye-zwiebel & King, 2014; Karmeback *et al*., 2015; Wairore *et al*., 2015; Abate, 2016). The key informants were interviewed and asked to describe: the factors or indicators they use to evaluate suitability of a particular range for livestock grazing; the methods they apply to rate the condition of the range and what measures they take when the condition of particular range was deemed too poor for grazing.

Observation was also used to compare the differences in vegetation cover and adjacent open areas and photographs taken to complement these results. The people of West Pokot have lived in this rangeland for a long time and they have indigenous knowledge of assessing rangeland condition in terms of the vegetation found in the area and what is palatable for their livestock, what is poisonous etc. Selection of knowledgeable herders (key informants like elders, chiefs) based on age and experience where interviews on broad issues related to indigenous range resource management techniques was conducted. Data collected through the questionnaires were analysed through descriptive statistical analysis and further reported using pie chart, bar graphs in percentages and frequencies.

4.3 Results

From the results of the study, it was evident that in Chepareria, majority of the farmers in the region rely on enclosures for grazing their livestock where they divide their land into paddocks and afterwards transfer the livestock to different paddocks after one area is exhausted of pastures.

Some farmers graze on both enclosure and open areas, grazing their livestock in the open areas during the wet seasons and take their animals to feed in the enclosures during dry seasons, i.e. November to March. 62% of the farmers interviewed graze in enclosures and open areas, 28% graze in enclosures alone and 10% graze in open areas as shown in (Figure 4.1). Those that graze in both enclosures and open graze in the enclosures from October to March (dry) and in the open from April to September (wet season). Those who graze in the enclosures subdivide their land into paddocks and carry out rotational grazing. When deciding where to graze, majority of the farmers check availability water and pasture.

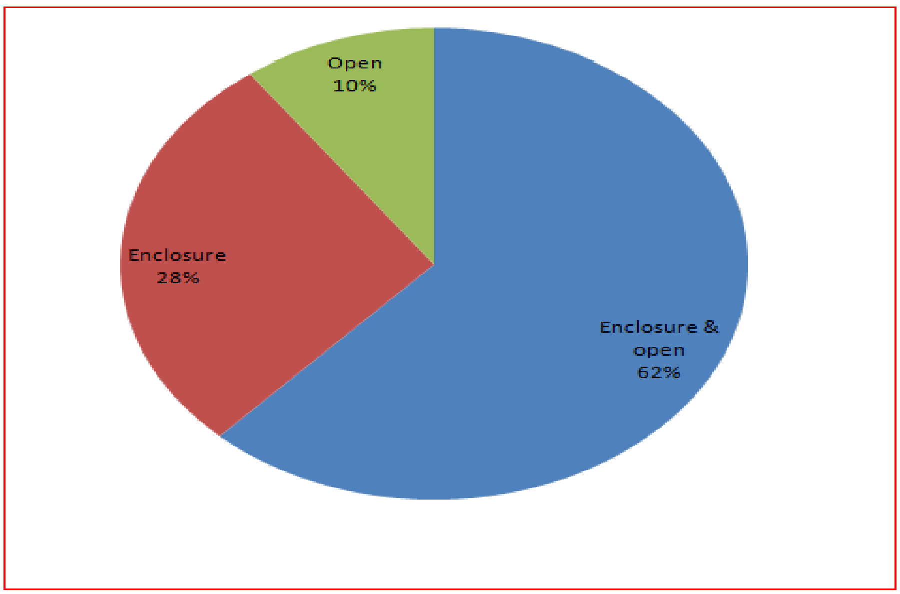

Figure 4.1: Preference of grazing areas in Chepareria, West Pokot Kenya.

When the land condition changes, the pastoralists responds in many different ways. Majority who have enclosures move to other paddocks, some farmers fence or enclose the land for some time to allow regeneration of pasture. In addition, others broadcast and spread manure; use preserved stovers of maize, buy hay or dried grass, feed the livestock on tree leaves like *Balanites aegyptiaca* while some migrate to other places where conditions are favourable or lease pastures from neighbours, or do destocking (Figure 4.2).

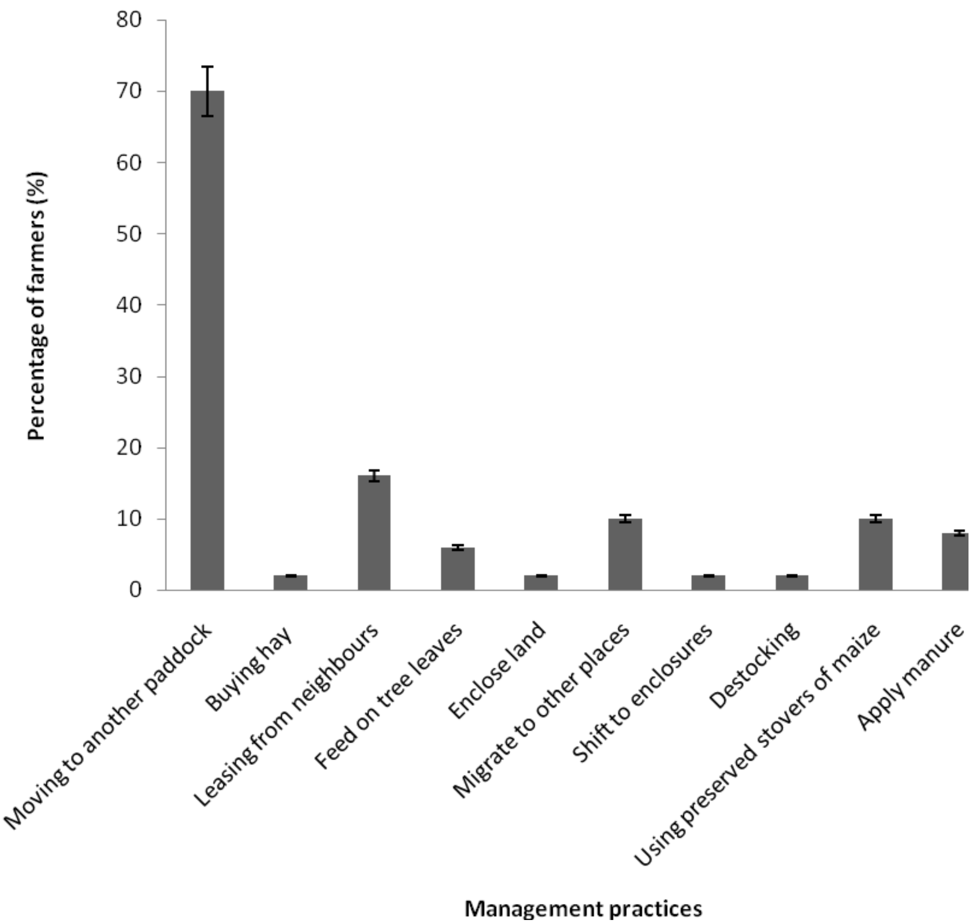

Figure 4.2: Grazing options for enclosure owners in Chepareria, West Pokot County

The condition of the rangeland has changed in the last twenty years. 98 % of the interviewed pastoralists claim there were changes witnessed in the area since the introduction and adoption of enclosures (Figure 4.3). This can be proved by the high herbaceous plant cover in the enclosed areas and low plant cover in the adjacent open areas, which have similar conditions like soils, topography, water and nutrients. Before enclosures were introduced, most of the places were bare with less vegetation and were severely eroded. With the introduction of enclosures by the Vi Agroforestry, the eroded parts have more plant cover now, even though one could see the depressions left due to erosion.

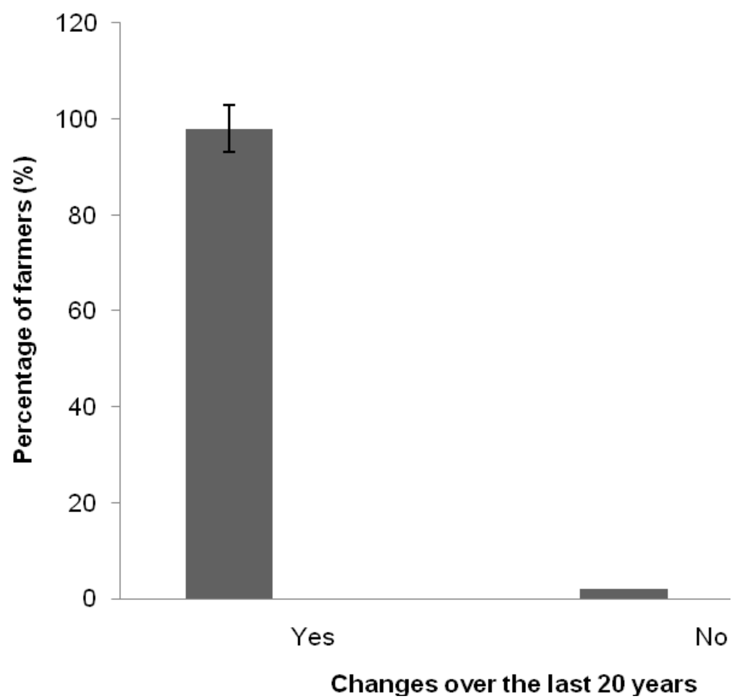

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Figure 4.3: Changes in range condition over the last 20 years in Chepareria, West Pokot Kenya

Before the Vi Agroforestry came into the area, people were practicing herding of many livestock but nowadays people are keeping small numbers of animals in paddocks. The changes can be attributed to the introduction of enclosures by the Vi Agroforestry a Non-Governmental Organization. They assisted the locals to dig terraces and gabions to prevent soil erosion, advised on the importance of keeping small herds of cattle which are more productive, people have settled down instead of moving with livestock from one place to another. The respondents agreed that the enclosures had brought changes in livelihood opportunities and also conflicts. The pastoralists in Chepareria not only depend on livestock alone, as was the case before but now they also carry out cultivation especially the growing of maize. They use some for subsistence and sold the surplus. Enclosures have led to increased pasture for livestock and thus high productivity.

Moreover they have kitchen gardens where they grow vegetables and rear poultry that complement their diet and sold them sometime to meet their immediate needs. In addition, women who traditionally used to stay at home to do the domestic chores like cooking, fetching water, washing and taking care of the children and family, now they take part in looking after the livestock and decision making of their sale and use. Some of the constrains associated with the enclosures include; boundary disputes where livestock trespass the enclosed areas, family disputes on grounds of land use where families have not subdivided their land, other people became landless since when the land was being subdivided people were given the land they had settled on, and thus they depend on the communal land.

Fencing the land modifies climate favouring the growth of trees and grass for their livestock (Figure 4.4). Fencing of land has enabled the pastoralists to close off their farms from livestock thus ensuring there is higher production of pasture for the livestock and also ensures crop production is done with minimal destruction by the livestock.

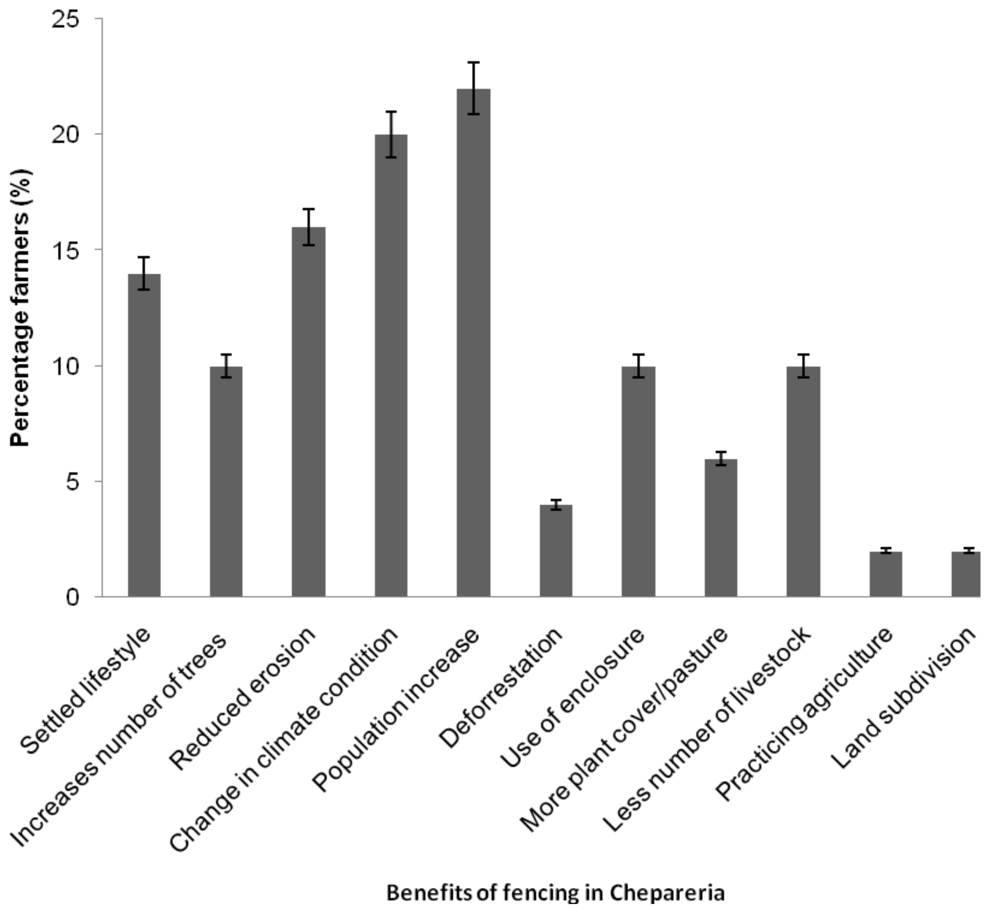

Figure 4.4: The impact of range closure in Chepareria, West Pokot Kenya

There are new species of trees and grass that have led to vegetation cover thus preventing soil erosion and also leading to an increase in the production of milk. The farmers now practice agriculture in their lands where they grow crops like maize, beans, bananas and vegetables. Most people own land as individuals and not as a community and thus have the incentive to take care for their land. The indigenous rangeland management practice still in use in the area is free range or herding in the communal land by some pastoralists.

Most farmers believe that indigenous knowledge on rangeland use and protection has not cascaded to the current generation. This is because they have embraced the use of enclosures and modern technology on cross breeding local livestock breeds and they have paddocks for grazing animals instead of grazing in the communal land. Enclosures are advantageous since there is more and improved pasture, leading to high milk production and the surplus is sold to generate income for the farmer, there is less movement of livestock thus it is easier to control parasites and diseases in livestock, it easier to control soil erosion, land disputes have reduced with the introduction of enclosures since land is individualised and closed off, hence minimal interference; people stored the excess pasture and maize stovers on trees for feeding livestock during dry season.

Some of these benefits include the following (Figure 4.5).

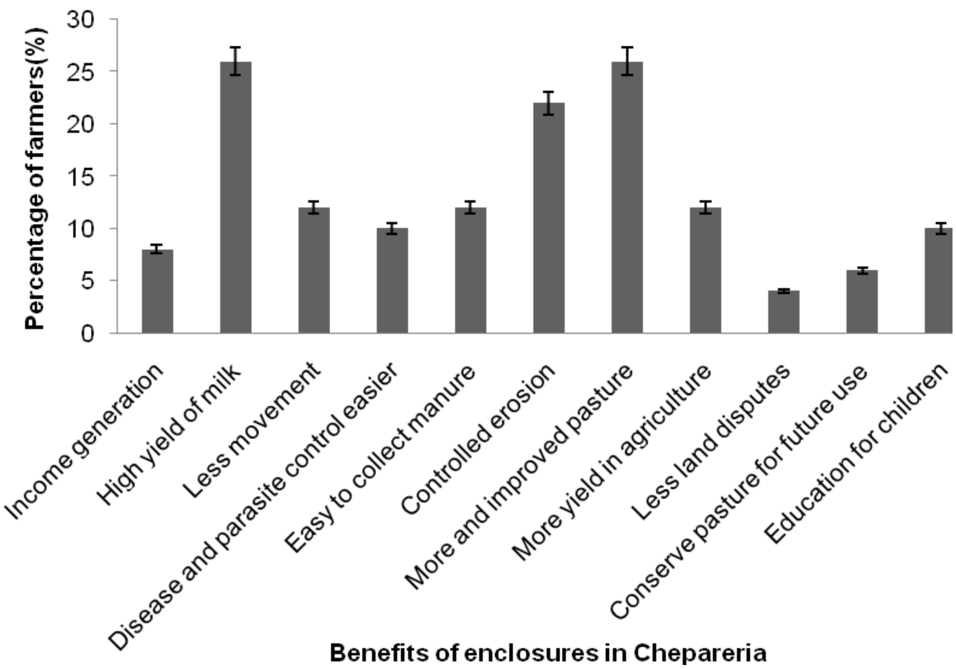

Figure 4.5: Benefits of enclosures in Chepareria, West Pokot Kenya.

Those pastoralists who have not enclosed haven't done it because their land has not been subdivided; some hold onto the culture and traditions of open and free range grazing, others the land is too small to be subdivided. The local people have reported that species that disappeared long time ago have been restored following establishment of enclosures. Traditionally the primary use of enclosures was for food production mainly maize, beans, sorghum, millet and cassava. Thorny twigs and branches from local trees are used to make the enclosures and later they are enforced by euphorbia, aloe or sisal live fence.

The enclosures were established using family labour or communal labour. Livestock were allowed into enclosures during the dry season and after harvest in the agricultural land. The standing biomass inside the enclosures is normally reserved for dry season grazing from October to March. Plant and animal diversity in enclosures increases with time after establishment. Where they had been established, enclosures are among the green spots with considerable species diversity. Enclosures have led to change in land access right. Land ownership has changed; individuals own land, some having the title deeds.

Moreover land disputes amongst the pastoralists in Chepareria have reduced since land has been subdivided and demarcated (Figure 4.6).

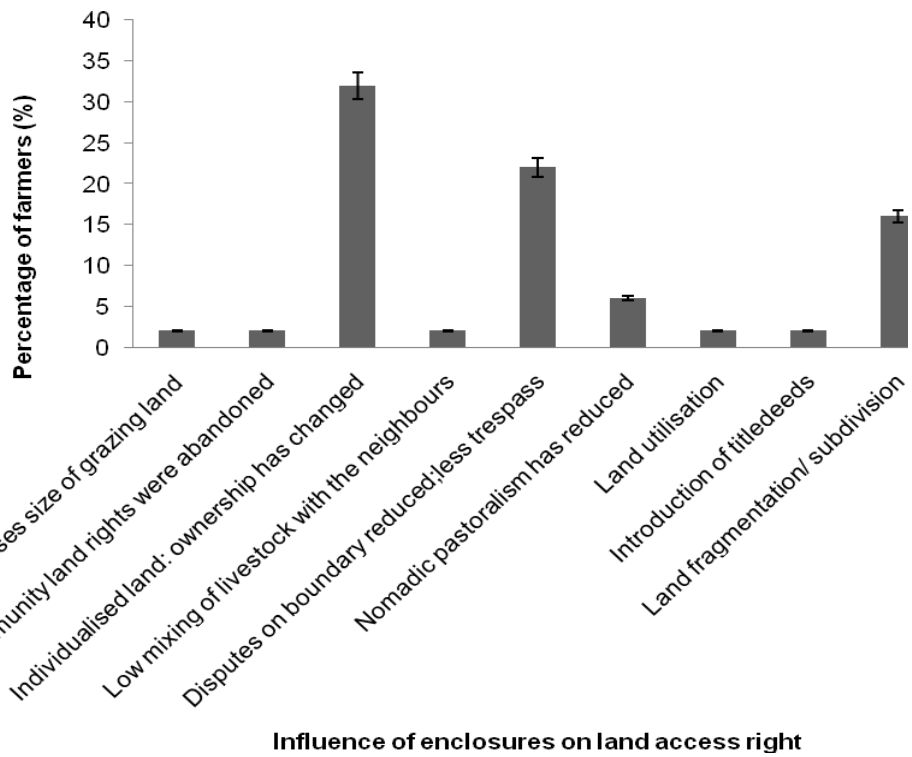

Figure 4.6: The influence of enclosures on land access and user rights Chepareria, West Pokot Kenya

Afforestation helps control soil erosion, provide feeds to livestock especially during the dry season; some trees have medicinal value to both human beings and livestock. Some of the herbs fed on by the livestock helped in controlling tropical diseases thus improving their immunity. Trees provide shade, building materials and act as source of firewood. From the results, it is evident that there are plants that had disappeared but now exists with the introduction of enclosures (Figure 4.7).

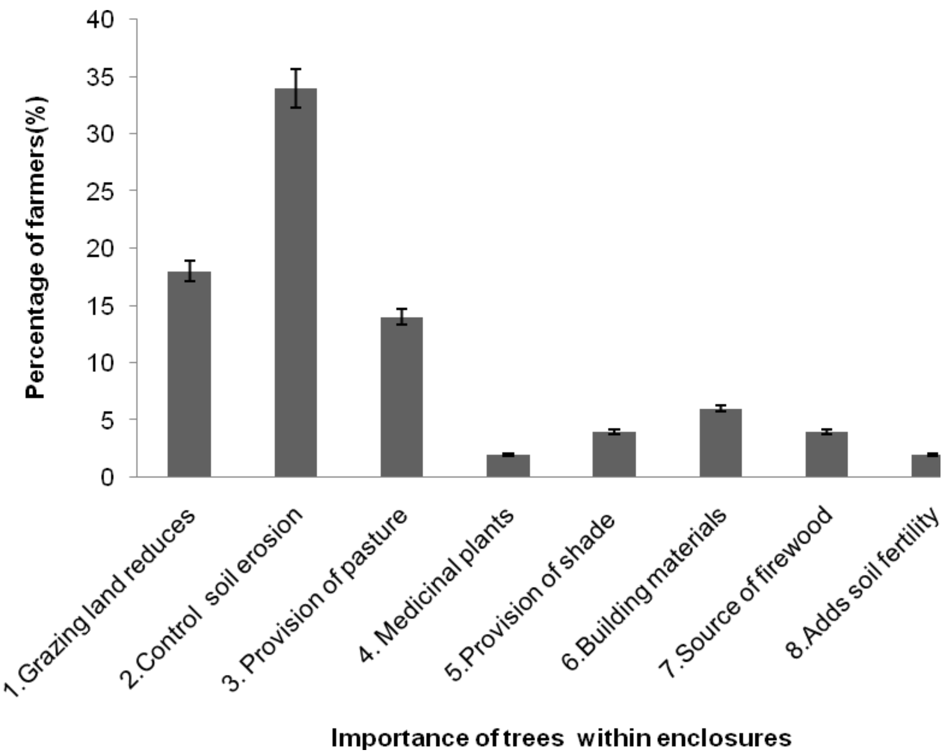

Figure 4.7: Significance of afforestation within the enclosures in Chepareria, West Pokot Kenya

From the study it was evident that majority (90%) of the residents believed that there were some plants that existed and then disappeared for sometimes because of degradation, but with the introduction of the enclosures they reappeared (Figure 4.8). Code 1 represents yes while 2 represents no reappeared. This shows that they were stored in the soil seed bank but the harsh environmental conditions could not favour their germination. However, with the introduction of enclosures, the plant cover helps to retain moisture and hence other plants regenerated.

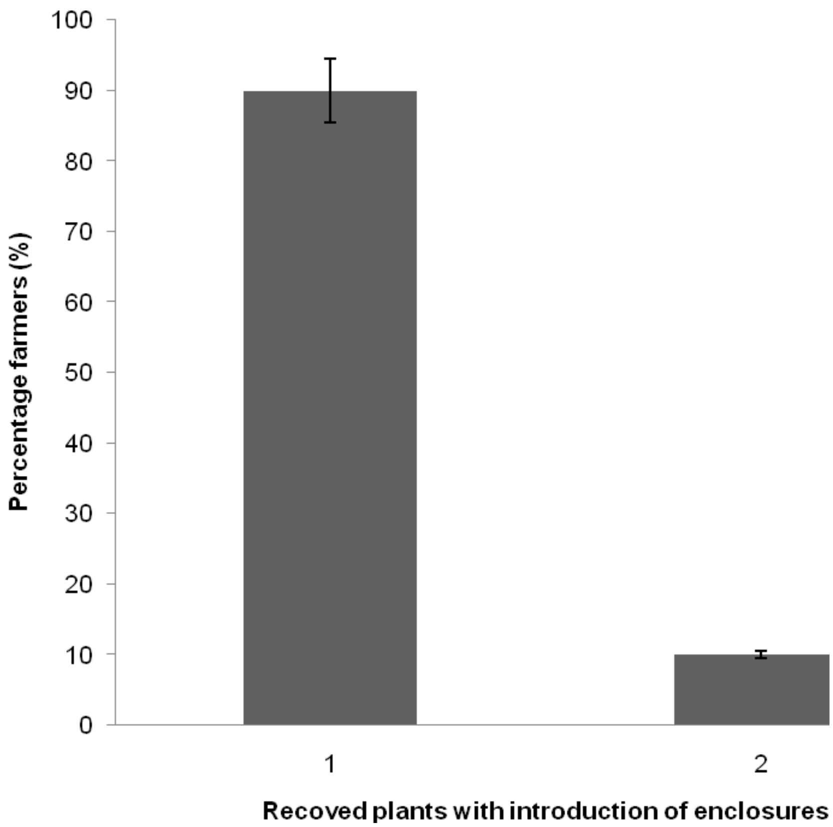

Figure 4.8: Recovery of plants with introduction of enclosures in Chepareria, West Pokot Kenya

There are different types of fences; live plants and dead cut thorn bushes. Some pastoralists combine live and dead fences (cuttings from shrubs and thorny trees), others use live fences like aloe, sisal, euphorbia and *Lantana* while very few use the barbed wires (Figure 4.9). There are about 38% farmers who use live fences alone, 52% use both live and dead fences and only about 4% use barbed wire. It shows that 90% of the population use live and dead fences that constitute of the locally available materials.

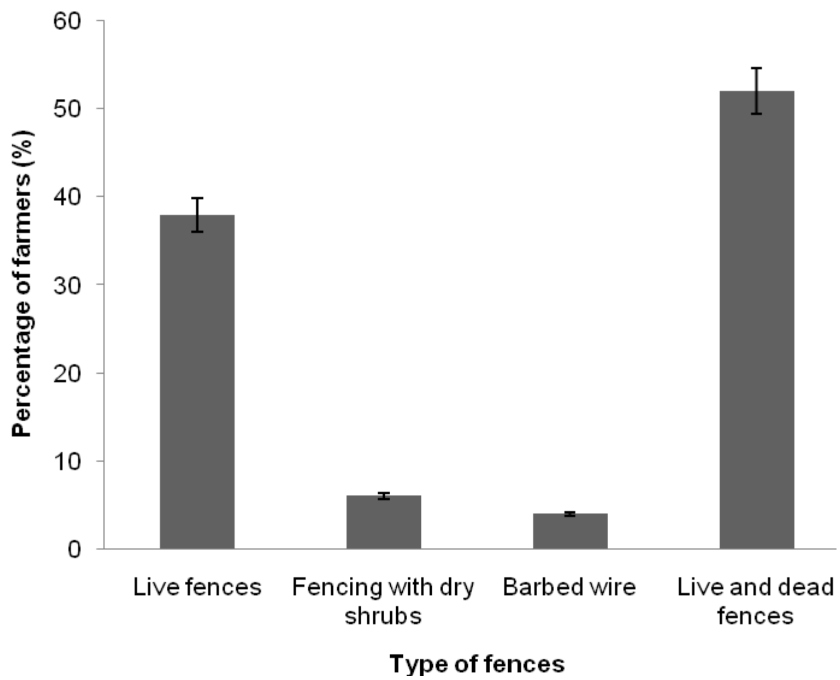

Figure 4.9: Types of fences used in Chepareria, West Pokot Kenya.

There were two main types of enclosures in Chepareria; communal and private. Pastoralists in the area used both types of enclosures (Figure 4.10). Majority (70 %) use the individual enclosures, while very few rely on the communal enclosures.

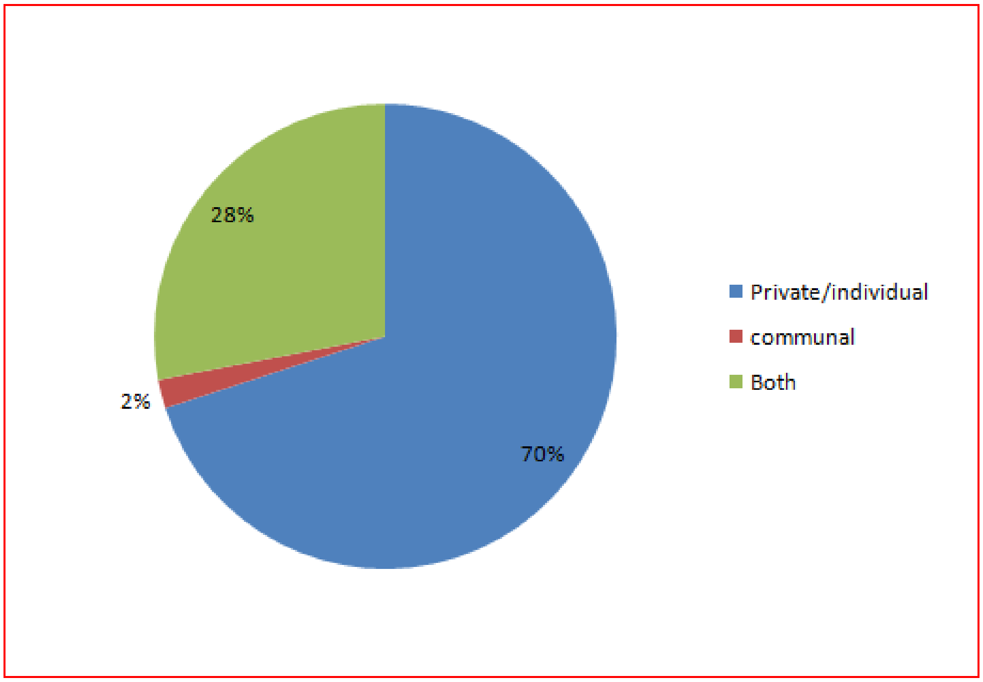

Figure 4.10: Types of enclosures employed in Chepareria, West Pokot

4.4 Discussion

In Chepareria, West Pokot, it is evident that the pastoralists have embraced the use of enclosures because of the benefits they derive from them. It has helped them deal with scarcity of pasture in the area, and problems faced by pastoralists like their death and that of their cattle, as a result of cattle rustling and tropical diseases like Trypanosomiasis. About 90% graze in enclosures, and hardly do they move from Chepareria in times of scarcity of pasture. Those that move, do so only to the plains within the area, since they store pasture for the dry season either in the fields or in stores.

Understanding peoples' attitudes and addressing their needs and priorities towards successful utilization and management of common resources such as forest/woodland resources is critical (Kasim *et al*., 2015). Establishing area enclosure is one approach of managing degraded forest/woodland (Kindeya, 1997; Tefera *et al.,* 2005). In Chepareria, majority of the respondents had a positive attitudes and perceptions towards the conservation of rangeland through enclosures in their locality, which could indicate that there was strong local peoples' commitment to combat land degradation. Similar result was reported by Ambachew (Kasim *et al*., 2015) on community participation in establishment and maintenance of enclosures. The study made by Tefera *et al*., (2005) showed that participation of leaders and members of the local community were so important for the success of area enclosure in the rehabilitation of degraded land.

Mostly, the pastoralists who use enclosures subdivide them into paddocks for rotational grazing. After the long rains when the pasture is abundant, they harvest grass and store it for the dry season grazing and then release the livestock to graze in the remaining pasture. This way they hardly lack pasture for their livestock. Pastoralists who have many livestock, they lease land from the neighbours who have plenty of land and fewer livestock at a cost. This was also noted by Wairore et al., 2015. Those that have less land graze in the open communal land and the plains of hills in the area. In the area, agriculture is carried out and after harvesting, stovers of maize are stored for dry season grazing and the remaining are grazed upon by releasing the livestock into the fields. Pastoralists also rely on trees like *Balanites aegyptiaca* for the dry season grazing since it is evergreen and its leaves are used as fodder and vegetables to the residents.

The condition of the land in Chepareria has changed, since the introduction of enclosures in the area by the Vi Agroforestry as a method of rehabilitating the dry land (Makokha *et al*., 1999; Triple L 2013). Before that, land used to be bare and pasture was scarce, nomadic pastoralism was widely practiced in the area (Makokha *et al*., 1999). Nowadays with the introduction of enclosures, pasture is abundant and available throughout the year and thus the pastoralists do not move with their livestock. They have a more settled lifestyle. Land has been subdivided among the sons and they keep less livestock that they manage well.

Enclosure have many benefits (Wairore *et al*., 2015) with more and improved pasture, due to manure from the livestock, the animals are producing more milk than before, which the people use to feed their children and sell the surplus at Chepareria market in the morning and evening. Animals do not move for longer distances and thus the energy conserved is used for milk and meat production. Diseases and parasite control has become easier as livestock do not mix with livestock from other areas and they have a common cattle dip that they use fortnightly to help them control parasites like ticks.

There is more pasture, some which is sold and earn income to the enclosure owners. The pastoralists keep goats and poultry that they sell to meet their basic needs like educating their children. With the establishment of enclosures, individuals owned and could properly man- age the land. Results were recorded to be increased pastures availability, dry season grazing reserves and more reproductive and healthier animals for enclosure owners (Makokha *et al*., 1999). Consequently, as more individuals enclosed land, there was reduced pastoral migration (Makokha *et al.,* 1999). Men were therefore free of their traditional role of herding, as animals only needed to be left to graze in the enclosure, taken to the river and back. Women on the other hand had more animals to milk, more productive land to tend and school-going children to attend to in addition to their domestic tasks (Karmeback *et al*., 2015).

Since primary education became free and compulsory in Kenya in 2003, formal education has become more accessible to Pokot children. This has led to changes in the household economy, caused by the connected schooling costs and other monetary requirements because, even if primary education has officially been provided free of charge since 2003 in Kenya, several monetary needs arise when sending a child to school, such as for books, uniforms and other expenses. This is a contributing factor for women to become increasingly involved in the monetary economy, as they are present in the household and therefore often the ones the young children turn to for small monetary needs.

These petty household needs are not ranked as necessitating the sale of sheep and goats by the male household head (Karmeback *et al*., 2015). Consequently, women have to plan, prepare and invest adequately for these expenses. It is therefore not surprising to find women parading roasted maize, bananas, avocadoes, mangoes and sugarcane for sale on the Kapenguria- Kainuk roadside in Chepareria (Karmeback *et al*., 2015). The same applies to milk at dusk and in the early mornings. The surplus of these agricultural products has only been readily available locally since the people of Chepareria started enclosing their land (Karmeback *et al*., 2015).

Enclosures have changed the land access right in Chepareria, as the land is owned by individuals, and though in some areas title deeds have not been issued, land has been subdivided and enclosed either using live fences or dead ones like cutting cactus, Acacia, Lantana and enclosing their land. Majority use live and dead fences. There are fewer disputes since land is individually owned and has demarcation. The land disputes have reduced as the enclosures prevent people and livestock from getting into ones farm; each person respects the boundaries and rarely intrudes their neighbour's land, unless the animals break in and this is settled with the elders.

Nomadic pastoralism in the area has reduced as they have settled and there is less movement. Enclosures in the area are individualized as those with no enclosures graze in open/communal land. From the study, it was clear that, there are some plants which had disappeared, but now exists with the introduction of enclosure. These are *Zanthoxilum chalybeum, Senna didymobtrya, Kigelia africana, Acacia albida* among others. Mureithi *et al*., (2015) and Verdoodt *et al*., (2010) reported the reappearing of species that had disappeared after severe degradation according to the locals in Laikipia and Baringo, respectively, after the areas were restored.

Good range condition has adequate forage, short distance to water and rare disease incidences. Afforestation has positive effect on the range health because when leaves fall and decompose, they add fertility to the soil especially the leguminous trees. Fair range condition has adequate forage, short distance to water and many disease incidences. Poor condition has inadequate forage, lack of water/ long distance to water and fewer disease incidences. The Sukuma people of Tanzania have local knowledge that they use to determine the range land condition and its trend. According to research by Selemani *et al*., 2012, the respondents used "plant growth condition" as an indicator of quality of rangeland, whereas the colour of vegetation is used as an indicator of range quality. Plant species diversity, animal plant species preference, quality of soil, rainfall, accumulation of plant litter and animal body condition score were also stated as indicators of range condition.

The twigs and leaves are also used to feed livestock thus improving their productivity. The most common tree in Chepareria is *Balanites aegyptiaca* whose leaves are used as vegetables and also feeding livestock. Trees provide shade to the livestock, act as wind break, herbs are used as medicine and they hold the soil firmly and thus control soil erosion. Most of the indigenous trees are found in enclosures though when not well managed they form thickets which are in some cases impenetrable for the livestock. In poorly managed enclosures, invasive species like *Lantana camara* occupy the grazing area forming thickets and prevent other herbaceous plants like grass from growing. This reduces the grazing resources for livestock.

The people of Pserum location, in Chepareria have dug a dam where rain water collects and they get water for their livestock to drink during the dry season. This has helped the herders not to waste a lot of time moving with the livestock for long distances in search of water. In addition to this, animals conserve energy they could have used to walk for long distances and thus that energy is used in improving the livestock productivity. Some of the soil and water conservation practices in the area include constructing terraces during the dry season, ditches, planting sisal and aloe across gullies, building of porous dams or gabions and tree planting.

Interviewed households acknowledged that enclosures have improved their lives through grazing, firewood collection, environmental conservation and controlled soil erosion. These findings are similar to those reported by Barrow and Shah (2011), which asserts that ngitili practice (use of enclosure) relied on indigenous knowledge, has successfully enabled protection of environment and improved livelihood of communities in Shinyanga region. Ngitili evolved in response to acute shortage of foraged due to drought and diminishing of grazing land as a result of increased number of livestock, cropping and shortage of herding labour.

4.5 Conclusion

The benefits of enclosures in this semi arid area outweigh the disadvantages and therefore embraced by the people of Chepareria. Mostly, the Pokot graze their livestock within the enclosures. They use locally available materials for making the enclosures. Grazing of livestock within the enclosures is beneficial for the regeneration of grass and other herbaceous plant species. Land in Chepareria is individualised.

CHAPTER FIVE

EFFECTS OF ENCLOSURES ON SOIL SEED BANK AND SOIL PROPERTIES, IN CHEPARERIA WEST POKOT KENYA

5.1 Introduction

Overgrazing and excessive utilization of rangelands has caused vegetation and soil degradation in many rangelands. Soil, one of the most important elements of rangeland ecosystems, is the source of food and moisture content for rangeland plants (Saffariha *et al*., 2014). Over grazing is one of the most important factors causing rangeland degradation, which is effective on vegetation and soil. There are various methods that are used significantly in rangeland restoration and the use of enclosures is one of them (Solomon, 2011; Yan *et al*., 2012; Yang & Li, 2013). Soil seed banks are considered as essential constituents of plant communities as they contribute significantly to ecological processes (Roosaluste *et al*., 2007; Shen *et al*., 2007).

Many studies have demonstrated that vegetation restoration partly depends on the ability of viable seeds to persist in the soil seed bank as a remnant of the past or present plant community (Solomon, 2011). A soil seed bank refers to the seeds that can remain dormant for a period of time in the soil until their germination is triggered by a local environmental change (Romo & Bai, 2004; Reubens *et al*.,2007; Olano *et al*., 2012; Li *et al*., 2014). The soil seed bank is the natural storage of seeds (Zaghloul, 2008).

It represents the regenerative potential of plant communities thus it could be important in conservation and restoration of vegetation. Soil seed bank plays an important role in restoring and managing degraded rangeland. Seeds from the previous plant species may have survived below degraded plant communities (Esmailzadeh *et al*., 2011). Soil seed bank represent a pool of reproductive potential and source of genetic inheritance and play an important role in vegetation establishment after a disturbance (Esmailzade *et al*., 2011; Espinosa *et al*., 2013).

The longevity of seeds is very variable and can change from nearly zero to several hundred years. Soil seed banks play an important role in the natural environment of many ecosystems. It is an important component of vegetation restoration and a good indicator of grassland management and of restoration practices (Bossuyt & Hermy, 2003; Amarasinghe *et al*., 2007; Biao *et al*., 2015). The mortality of seeds in the soil is one of the key factors for the persistence and density fluctuations of plant populations especially for annual plants (Shang *et al*., 2013). The soil seed bank is the natural storage of seeds; dormant in soils of ecosystems. Seed bank plays a role in composition of different plant communities (Ma *et al*., 2010; Parlak *et al*., 2011; Ma *et al*., 2012).

Composition of seed bank depends on production and composition of the present and the previous aboveground vegetation and longevity of seeds of each species under local conditions. Soil testing plays an important role in crop production and nutrient management. Enclosure is widely used to restore degraded grassland in Tibetan plateau and has proved effective in improving pasture composition and soil mineral status (Shang *et al.*, 2013). This study aimed at examining the effects of enclosures on soil seed bank and soil properties therefore, assist to manage the present vegetation in the area and restore the disappearing vegetation.

5.2 Materials and methods

Enclosures in Chepareria were established since 1986 by Vi Agroforestry. In order to evaluate the effect of enclosures on soil properties, enclosure and open areas were selected in the region in 2014. The enclosure and open sites were in close proximity and were located in the same homogeneous ecological units (Walworth, 2006; Saffariha *et al*., 2014).Soil samples were collected from the study site described in chapter two. Forty two samples were collected, twenty one in the enclosures and twenty one in the open areas. Sampling was done in the dry season between November 2014 and January 2015, in the Modified Whittaker plot measuring 50m x 20m in twenty one enclosures and twenty one in open areas adjacent to the enclosures.

Ten soil samples were collected from each of the ten 0.5m by 2m quadrats in the Modified Whittaker plot. Quadrat of 0.5mx20m were laid out, 10 samples from each site were randomly collected using a metallic tube with 5cm diameter and 20cm depth. The ten cores of soil were mixed to reduce variability and a sub sample of 750cm^{3}takenfor soil nutrient and soil seed bank analysis. Roots and other debris were removed from the sample.

The soil was put in and placed in khaki paper bags and transported to the laboratory, for the soil seed bank and properties analysis. A sub sample was put in germination trays for soils seed bank assessment. Germination trays were placed on benches in green house, watered daily and germination observed was noted and recorded. One week after placing the seeds in the greenhouse, for germination the first seedlings emerged, were counted and recorded. The number of seedlings that germinated per sample was used to compute the soil seed bank density using the area of the core. The remaining soil of each sample was used for the chemical analyses for the following soil properties: pH, potassium, nitrogen, calcium, magnesium, sodium, phosphorus and micro nutrients like manganese and copper were tested (Walworth, 2006; Horneck *et al*., 2011; Muturi *et al*., 2014).

5.3 Results

Overall a total of 44,960 seedlings germinated from soils collected in the enclosures and 23,360 seedlings from soils collected from the open areas. The soil seed bank in the enclosures was significantly higher.

The seeds collected in the enclosures were twice than in the open areas (t_{40}=-3.21, $P<0.001$) (Figure 5.1). On average, about 2141 seedlings were in the enclosures and 1112 in the open areas respectively.

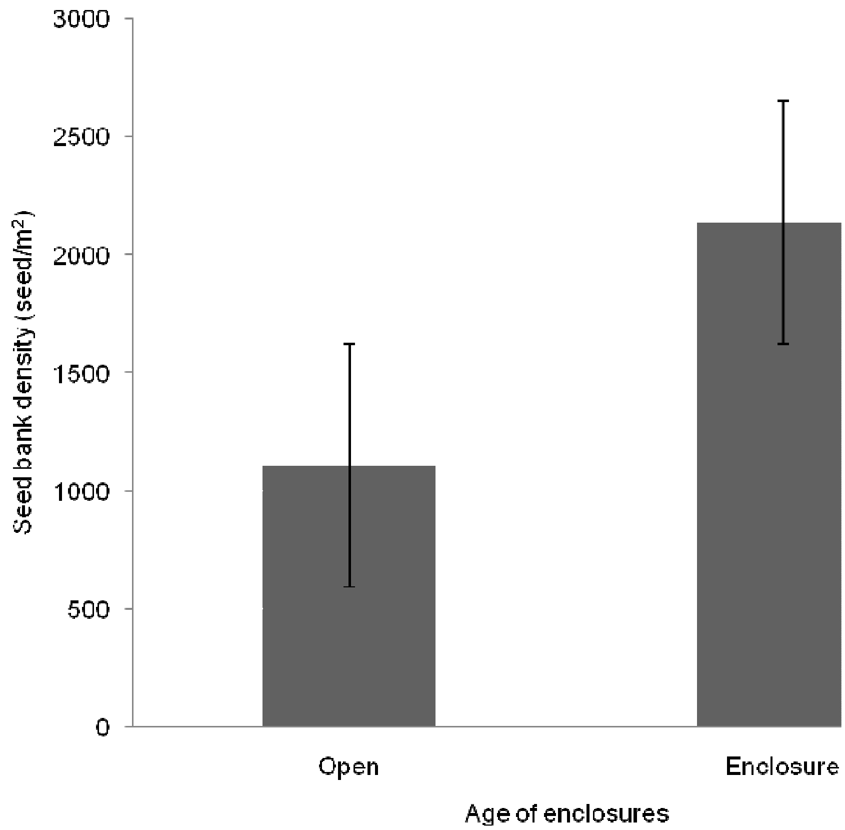

Figure 5.1: Seed bank density in the open and enclosed areas in Chepareria, West Pokot Kenya

Grasses dominated the germinated seedlings in the green house experiment. Seedlings germination differed at different times of enclosure. The younger enclosures (1-5 years old) had slightly lower seedling germination (2347), as compared to older enclosures; 6-10 years old 2400, 11-15 year old enclosures had an average of 2667 seedlings that germinated. The enclosures between one to fifteen years the average number of seedlings that germinated was increased with increase in the age of enclosures, but there was a slight decline in the trend with the enclosures above 15 years (average of 2053). In the enclosures there are more seedlings that germinated, compared with open areas.

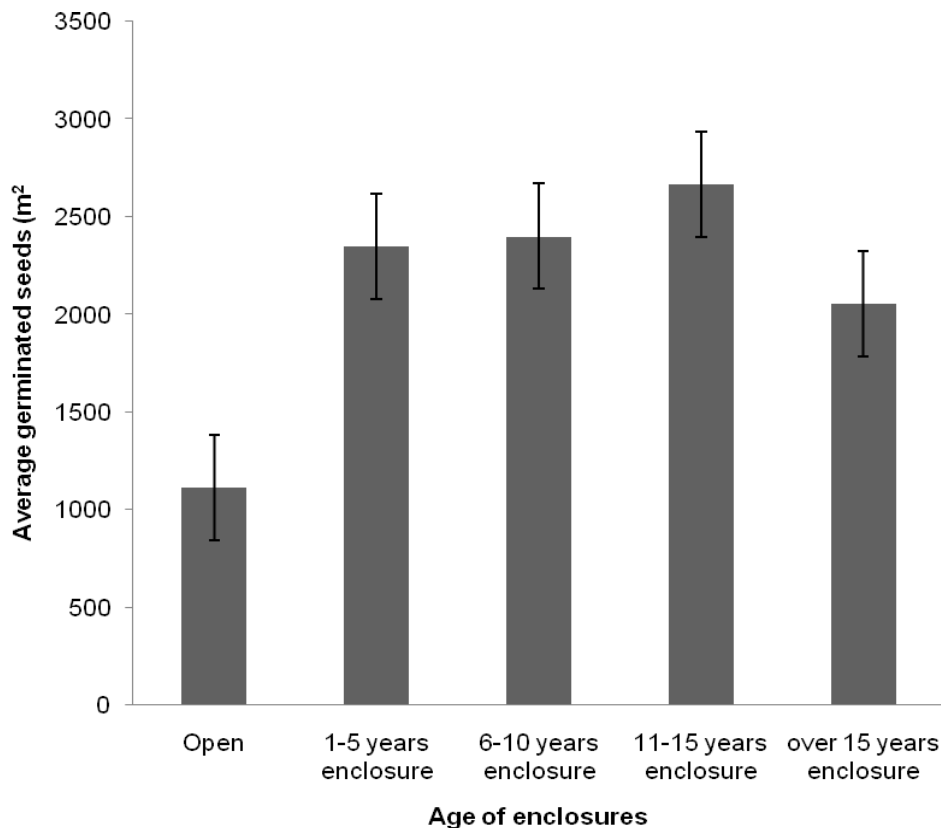

Figure 5.2: Average seed germination at different ages of enclosures in Chepareria, West Pokot Kenya

Enclosures had some effect on soil properties. Although nitrogen was low in both types of range use, it was significantly higher in enclosure (table 1). Phosphorous and calcium was adequate in the enclosures but low in the open areas. Manganese was also higher in enclosures but still adequate in the open areas. Use of enclosures had no effect on other soil properties (table 5.1)

Table 5.1: Comparison of soil nutrient levels in enclosures versus in open areas in Chepareria

	Enclosure			Open			P value
Soil parameter	Mean	±se	Class	Mean	±se	Class	
Soil pH	6.16	0.09	Acidic	6.03	0.12	Acidic	0.200
SOC (%)	1.90	1.41	Moderate*	0.32	0.05	Low	0.134
N_{tot} (%)	0.09	0.02	Low	0.05	0.00	Low	**0.040**
P (ppm)	26.95	11.74	Adequate	5.60	1.11	Low	**0.030**
K^+ (Cmol (+) kg^{-1}	1.03	0.23	Adequate	6.36	4.23	Excess*	0.120
Na^+ (me %)	0.29	0.11	Adequate	0.67	0.19	Adequate	**0.050**
Mn^{2+} (me %)	0.48	0.18	Adequate	1.18	0.38	Adequate	**0.050**
Fe^{2+}(ppm)	30.04	2.89	Adequate	25.18	4.80	Adequate	0.200
Ca^{2+} (me %)	2.32	0.15	Adequate	1.75	0.19	Low	**0.010**
Cu^{2+} (ppm)	6.16	2.78	Adequate	2.30	0.35	Adequate	0.090
Zn^+ (ppm)	4.96	3.23	Low*	18.69	7.51	Adequate*	**0.050**
Mg^{2+} (me %)	2.50	0.24	High	2.81	0.27	High	0.200

N and Zn were low in enclosures, while the rest of the nutrients were adequate. Though nitrogen was also low in the open areas, it was still higher in the enclosures. Ca, P, N tot and TOC were low in the open areas but were higher in the enclosures. K, Na, Mn, Fe, Cu, Zn and Mg were abundant in the open areas. On average the pH was alkaline for both enclosed and open areas.

For Phosphorus there is a statistically significant difference in open and enclosure since the significance value is at 0.03 which is below 0.05. For calcium we can see from the table that there is a statistically significant difference in open and enclosure since the significance value is at 0.01 which is below 0.05. For Zn p =0.05, Na p= 0.05, Mn p =0.05 and N total p= 0.04 from the table there is a statistically significant difference in open and enclosure since the significance values is below or at 0.05. PH, (p=0.2), SOC, (p=0.134) K, (p=0.12) Fe, (p=0.2) Cu (p=0.09) and Mg (p=0.2) there is no statistically significant difference in open and enclosure since the significance (p) value was higher than 0.05.

Potassium level increased with period of enclosure then afterwards starts declining (Figure 5.3). Middle age enclosures (between 6-10 years) had very high potassium rate. In the open areas, K level was 0.45 me%, in the 1-5 years old enclosures K was 0.75 and in the 6-10 years enclosure it was 1.25 me% which was also the highest. From 11 years of enclosure and above, the level of K declined; 11-15 yeas 0.88 and over 15 year old enclosures it was 0.61 me%.

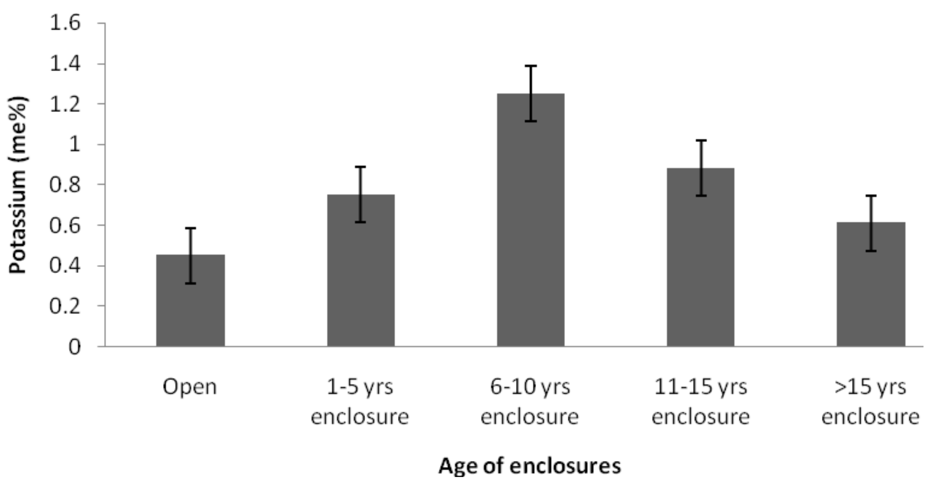

Figure 5.3: Amount of potassium in me% under different ages of enclosures in Chepareria, West Pokot Kenya

Magnesium level in Chepareria kept on changing; it is high in open areas (2.73 me %) than in some of the enclosures; 1-5 years old enclosures 1.84 me% and the 11-15 years old enclosures slightly lower than open areas 2.41 me% (Figure 5.4). Magnesium level is highest in the middle age enclosures (between 6-10 years).

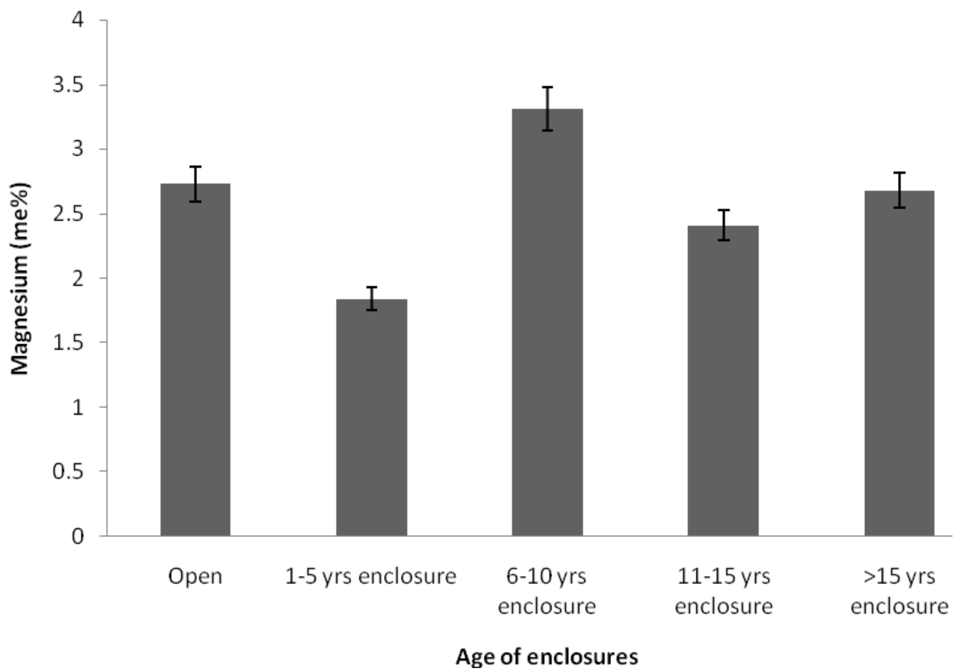

Figure 5.4: Amount of magnesium in me% under different ages of enclosures in Chepareria, West Pokot Kenya

Calcium level was almost equal in all the management; both open areas and enclosures. In the open areas on average Ca level was 2.24 me% and in the enclosures; 1-5 years old enclosures 2.4 me%, 6-10 years 2.07 me%, 11-15 years 2.46 me% and over 15 years it was 2.37 me% respectively (Figure 5.5).

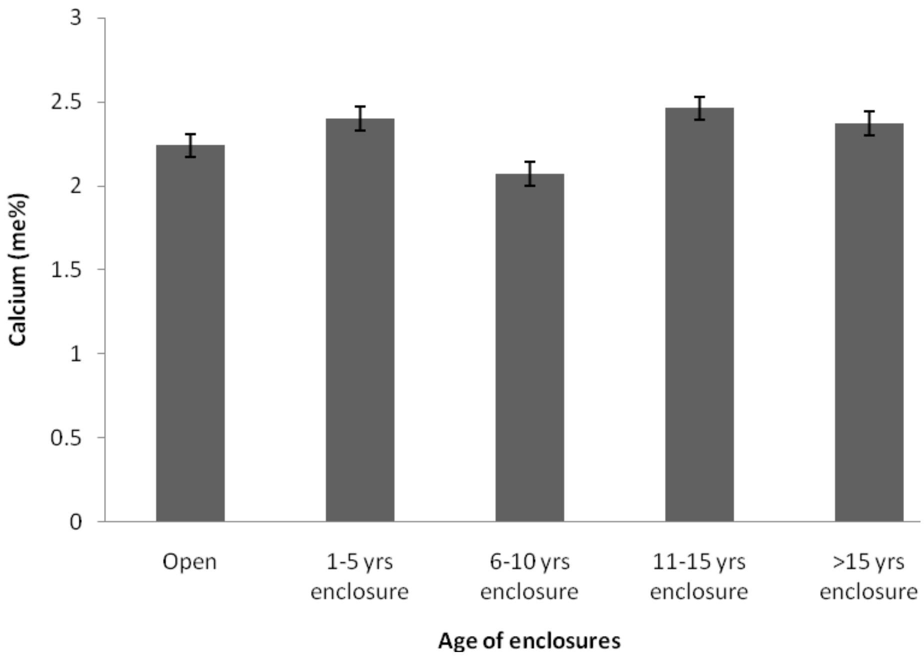

Figure 5.5: Amount of calcium in me% under different management in Chepareria, West Pokot Kenya

Soil pH changed under different management (Figure 5.6). In the open area average pH level was 6.07 weak acidic, and in the enclosures; 1-5 years was 6.54 weak acidic, 6-10 years 5.98 acidic, 11-15 years 6.23 and over 15 years old enclosure soil pH 5.82 respectively. Soil pH in the young enclosure (between 1-5 years old enclosure) was neutral, 6.54.

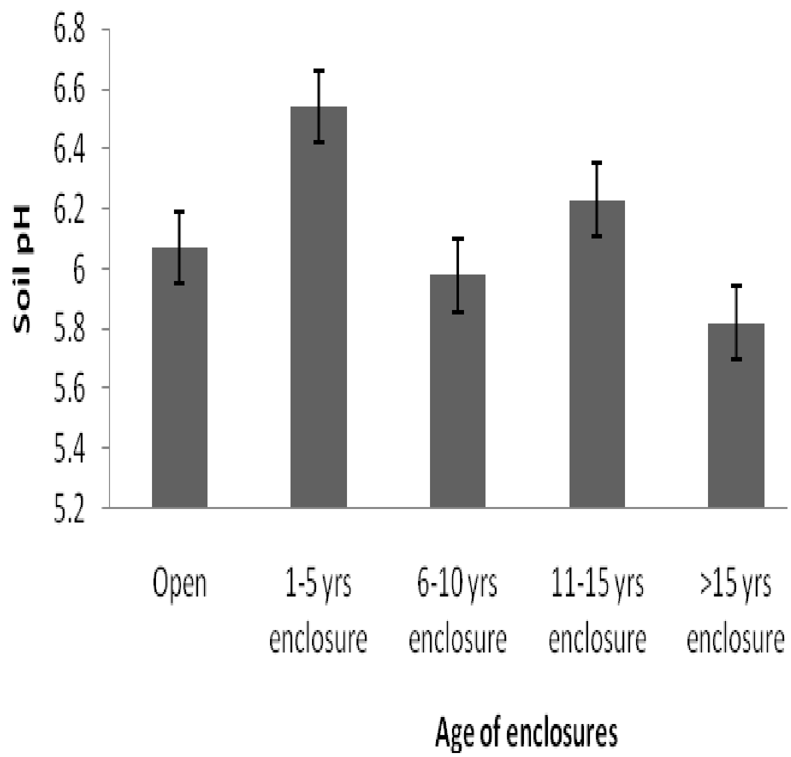

Figure 5.6: Amount of soil pH under different management in Chepareria, West Pokot Kenya

Total organic carbon increased with increase in the age of enclosure (Figure 5.7). The TOC was lowest in the open areas but there was an increase in the enclosures. In the open areas TOC was 0.36% and in the enclosures; 1-5 years TOC was 0.39%, 6-10 years 0.41% 11-15 years 0.44% and > 15 years 0.42%.

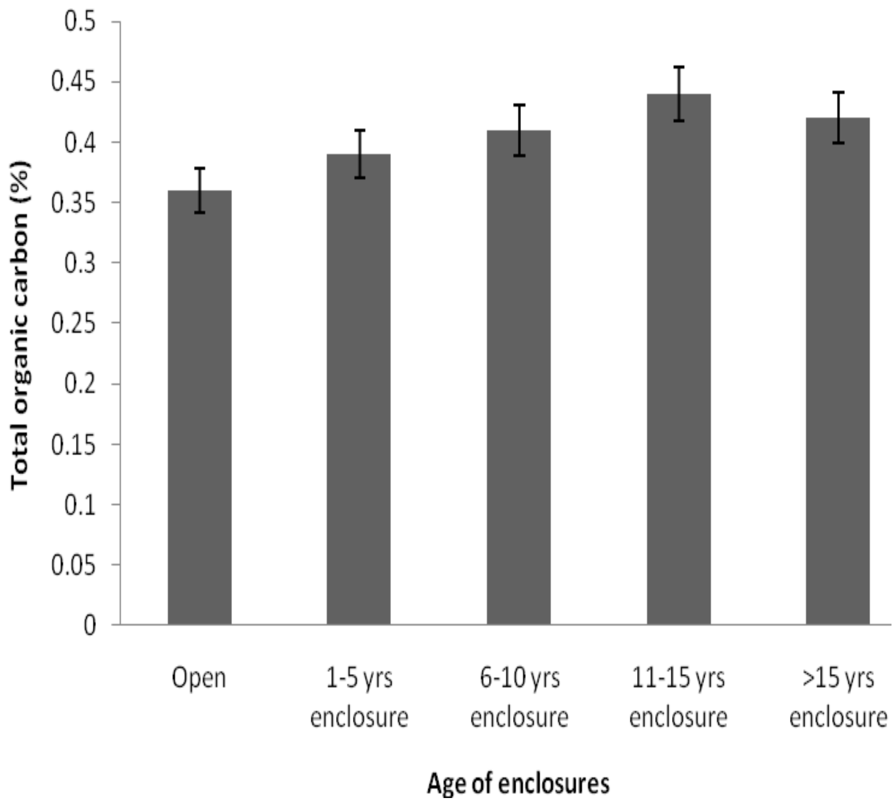

Figure 5.7: Total Organic Carbon % under different management in Chepareria, West Pokot Kenya

Phosphorus level in Chepareria was low in both open and enclosed areas; except the enclosures between 11-15 years old (58.13 ppm). In the other enclosures, P level was low; open areas 6.67ppm, 1-5 years 8.33ppm, 6-10 years 5ppm and > 15 years 10 ppm (Figure 5.8).

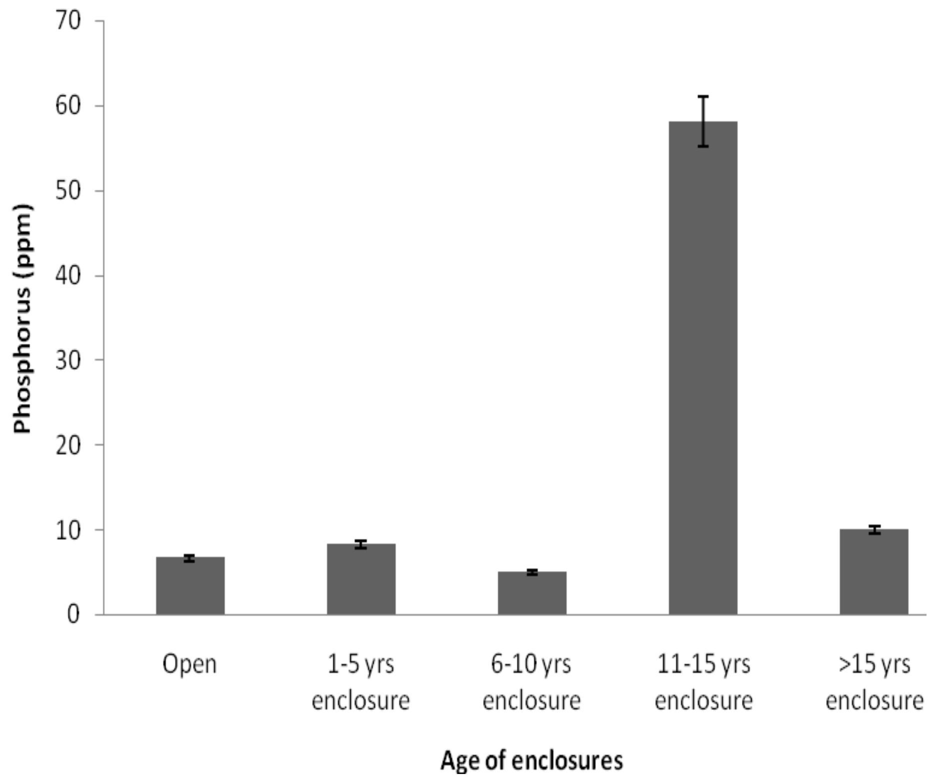

Figure 5.8: Amount of phosphorus ppm under different management, Chepareria, West Pokot Kenya

Copper level was almost equal in open and enclosed areas, though enclosure of 6-10 years old was the highest (6.08 ppm). Cu in the open areas on average was 3.23 ppm. The level of Cu then increased with the enclosures; 1-5 years 3.66 ppm and 6.08 ppm in the 6-10 years. There was a decline in the level of enclosures in the enclosures that were over 11 years old; 11-15 years 3.12 ppm and > 15 years 3.11 ppm (Figure 5.9).

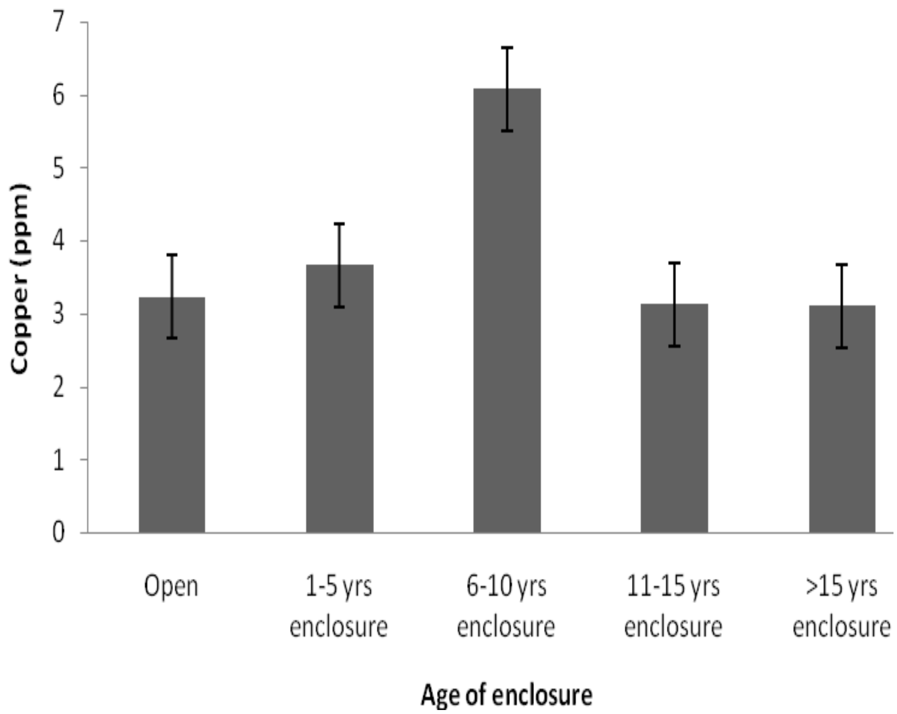

Figure 5.9: Amount of copper ppm under different management, Chepareria, West Pokot Kenya

The average amount of iron in Chepareria was high in both open and enclosed areas (Figure 5.10). Fe level was highest in the > 15 years old enclosures (37.11 ppm) and then the open areas at 35.03 ppm. In the other enclosures it was slightly lower; 1-5 years 31.27 ppm, 6-10 years 31.98 ppm and 11-15 years 25.84 ppm

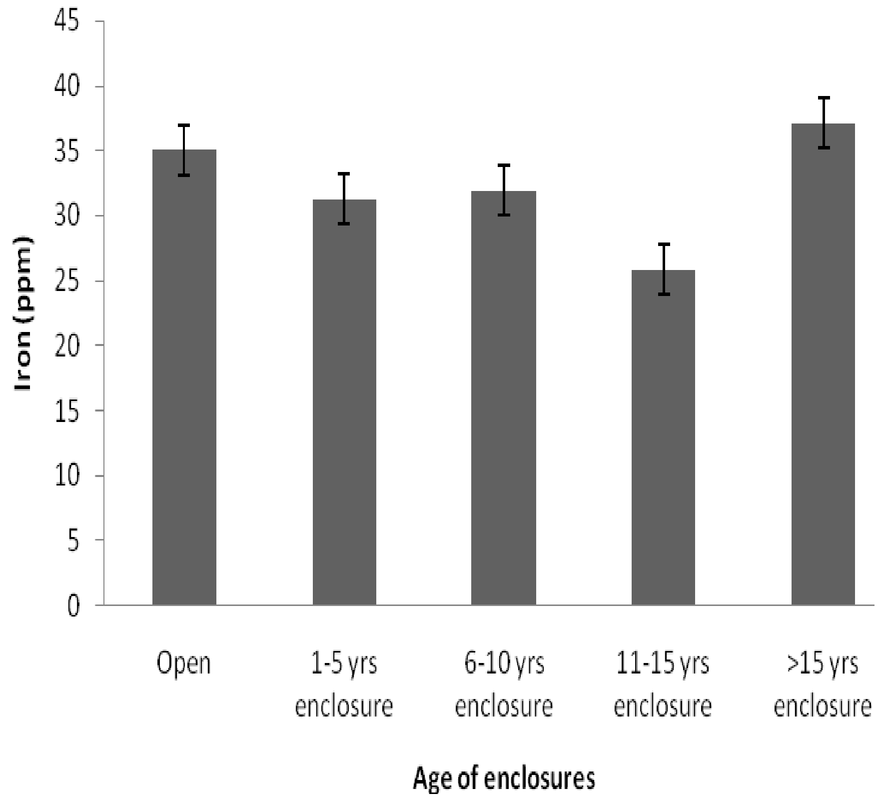

Figure 5.10: Amount of iron ppm under different management Chepareria, West Pokot Kenya

Manganese level in Chepareria was highest in the enclosures of 6-10 years (Figure 5.11). Mn level was highest in the 6-10 years enclosure (1.39 me %). In the open areas it was 0.671 me%, 1-5 years old enclosure 0.77 me%, 11-15 years 0.21 me% and >15 years old enclosures 0.26 me %).

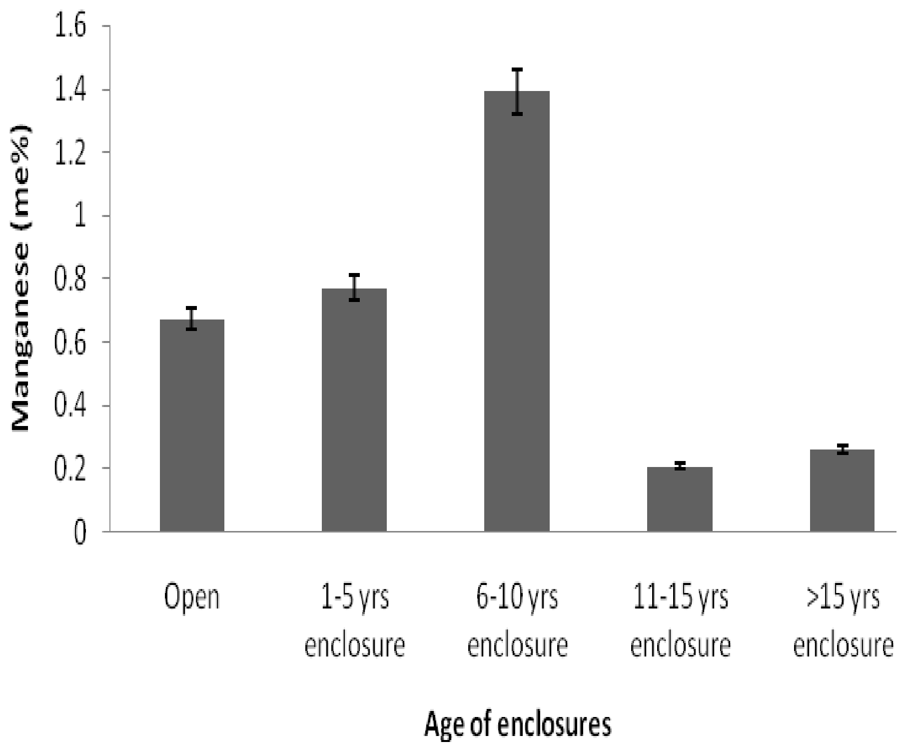

Figure 5.11: Amount of manganese in me% under different management, Chepareria, West Pokot Kenya

Zinc was highest in the open areas and enclosures below or equal to five years in Chepareria (Figure 5.12). Zn level was highest in the 1-5 years enclosure (2.46 ppm) and in the open areas (2.13 ppm). The other enclosures it was slightly lower; 6-10 yrs 1.47ppm 11-15 years 1.87 ppm and over 15 years 1.9 ppm.

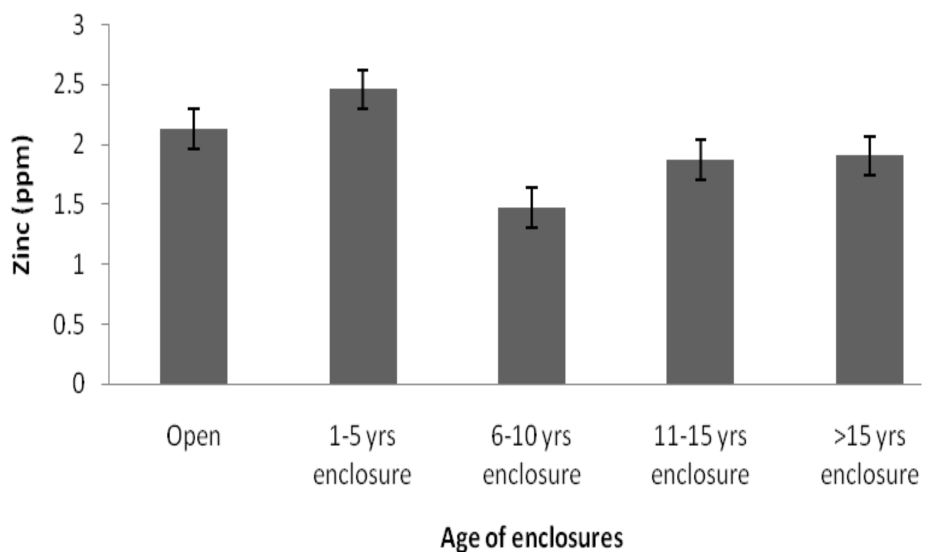

Figure 5.12: Amount of zinc ppm under different management, Chepareria, West Pokot Kenya

5.4 Discussion

Understanding soil seed bank of a particular habitat can assist to manage the composition and structure of existing vegetation and restore vegetation in many ways (Zaghloul, 2008). From the study, there were similarities in soil seed bank analysis and herbaceous cover in both the enclosures and open areas. This similarity proves that, even the open areas, if it can be enclosed, it can be rehabilitated and be a source of pasture for the livestock. Soil seed bank was low in the open areas but increased in enclosure with age. This can be related to the fact that open areas are more exposed to agents of erosion and have less cover thus most of the seeds are carried away by wind and water. The slight change in the trend of the increase in soil seed bank in the enclosures, where the over 15 years old enclosures was lower than the other enclosures, can be attributed to mismanagement or less management by the owners. Management practices were poor in some of these enclosures, where grazing was done throughout the years with no time for the plants to grow and mature and flower with minimal disturbance.

Enclosed areas are well managed and grass is allowed to grow and flower before being harvested or grazed upon. Most of the species with a high germination percentage were the annuals while the perennials were few. The samples in the green house were watered twice a day to aid in the breaking of the seed dormancy. Most of the woody tree species are hardy and their dormancy is broken by exposure to high temperatures. Collection of soil samples at the end of a dry season when most of the seeds were mature and dry, thus they could germinate if subjected to the right conditions.

Woody species in the enclosures, in the field were less. The trees and shrubs were few and scattered in Chepareria. They were more only in some enclosures where the farmers were involved in the planting of the trees. Lack of woody species in the soil seed bank can be attributed to low seed number and herbivory. This is similar to some studies done in Ethiopia where there were no seedlings of woody species (Birhane *et al*., 2007). Open areas had lower number of seedlings germination which could be attributed to grazing upon by animals after emergence or trampling by animals before they could grow and mature and produce seeds

The composition of species in soil seed banks depends on present above ground vegetation, seed rain from adjacent areas, seed longevity and previous above ground vegetation. Viable seeds in soil seed bank form the basis of restoration for the rangelands. High seedling emergence in enclosures can be attributed to seeds from above ground cover. However, some could be stored for longer time and may not be related to above ground vegetation. They can also be brought to the enclosures through soil erosion. Biodiversity also plays a major role in enhancing the restoration of enclosures. For instance, birds and other animals like monkeys aid in the transportation of seeds from one point to another.

High seedling emergence in enclosures can therefore be attributed to seeds from above ground cover. Similar studies by Olano *et al*., (2012) showed that there is a strong relationship between above ground vegetation and soil seed bank. In his studies, Olano, observed that heavy grazing affect soil seed bank, since the grazing livestock may prevent full plant growth, reducing the seeds production. Other studies in dry arid and semi-arid areas, rangelands, have reported similar results regarding the influence of increased grazing on the reduction of the soil seed bank (Erfanzadeh *et al*., 2015).

Most crops grow best when the soil pH is between 6.0 and 8.2. In Chepareria, the pH ranged from moderately acidic to slightly acidic. When the soil is acidic the availability of nitrogen, phosphorus and potassium is reduced, which are essential for optimum plant growth, and there are low amounts of calcium and magnesium (Horneck *et al*., 2011). Livestock grazing exclusion has a high potential to restore vegetation and soil and is an important alternative to stop further degradation and combat desertification in arid and semiarid regions. Many studies have shown that grazing exclusion enhanced plant cover and biomass and improved overall soil quality. The results this study indicated that grazing exclusion has a positive and significant impact on soil properties in the area. Soil nitrogen (N %) in enclosures had increased compared to open areas.

Foth (as cited in Verdoodt *et al*., 2010) outlined that vegetation cover strongly influences soil nitrogen content. Soils having good plant cover, aboveground biomass usually have more organic matter and nitrogen Therefore, in grazed exclusion sites, vegetation cover and root volume in soil result in an increase in nitrogen content compared with the grazed area. Heavy grazing results in a reduction of plant residues in soil which affects the supply of nitrogen and phosphorous (Saffariha *et al.,* 2014). Hosseinzadeh *et al*., (2010) noted areas which were non-grazed by animals had higher soil nitrogen content due to their dense vegetation cover, particularly nitrogen stabilizing plants like legumes and large volumes of plant roots in their soils.

Enclosures caused phosphorous content to increase compared with the open sites. This is likely due to those rangelands vegetation exploits phosphorous from lower depths so when vegetation cover and biomass are restored with enclosure, phosphorous accessed at deeper soil depths is brought to the surface and accumulates at the soil surface. Garcia (as cited in Saffariha *et al.,* 2014) also observed that the amount of phosphorus in enclosed areas was higher than the grazed/open area. The increase may have been due to the effect of climate conditions and soil fertility. The results of the present study are in agreement with the report by Hosseinzadeh *et al*, (2010). More vegetation remains, significantly increases soil phosphorus. Since when humus decomposes, phosphorus gradually releases in the soil.

Soil K amount in enclosure was higher than open areas. This is likely due to an increase in potassium transfer by plants to the upper soil layers accessed from deeper soil layers compared to the open areas as discussed above for phosphorous. The increase in potassium amount is also likely due to the increased vegetation and litter cover and improved soil properties in the enclosure treatment. These results are in agreement with the findings of Mofidi (as cited in Saffariha *et al.,* 2014) and Hosseinzadeh *et al*., (2010). Soil of enclosure sites have more dense grasses cover, more organic matter and available water, more plant roots and better aeration than grazed soils with less cover (Saffariha *et al.,* 2014)

Mekuria *et al*., (2007) reported strong increases in soil fertility, biological activity, and Carbon storage as a consequence of grazing enclosure. Steffens *et al.,* (2008) indicated that heavy grazing due to excessive reduction of vegetative cover, changes in plant growth form and animal trampling affect the amount of soil nutrients. As reported by Mofidi (as cited in Saffariha *et al* 2014) and

Hosseinzadeh *et al.,* (2010), grazing had negative effects on soil potassium content. Higher soil leaching rates caused lower potassium content in grazed /open areas. The results of this research is disagrees with the results Zarekia *et al*., (2012), who found that the high amount of potassium was observed in higher grazing intensity. The increase in potassium may have been related to livestock's positive effect on accumulation of potassium through trampling and their excreta.

Enclosure age also plays a role in conditioning the rehabilitation impact on soil properties, as reported by Mekuria (2006). Deficiency in Nitrogen could severely limit the yield of grasses in managed arid and semi-arid rangelands (Mureithi *et al*., 2014). The recycling of Nitrogen through animal droppings and urine during intermittent grazing is limited, resulting in an increasing Nitrogen depletion in the soil. Considering that fertilization under the existing climatic and socioeconomic conditions is respectively inappropriate and unmanageable, over sowing with legume fodder species and indigenous trees (e.g. *Acacia tortilis*) adapted to the local semi-arid conditions to improve total soil nitrogen is a feasible option. The herbaceous biomass production and cover are the catalyst of soil restoration (Mekuria & Yami, 2013).

5.5 Conclusion

The results of the present study showed positive effects of enclosures on soil properties and soil seed bank. The restoration of the soil quality in enclosures was successful compared to the open communal grazing areas. Soil fertility is attributed to the use of enclosure. Higher soil nutrients were noted mainly those in enclosed areas. Vegetation cover especially leguminous plants influences the contents of nitrogen in the soil.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The enclosed areas are more productive as a result of having more cover, biomass, tree density and species richness. Enclosed areas have more soil seed bank. The results of study showed significant positive effects on soil properties and after enclosing the land. The percentage of N, P and K in enclosures had increased compared with the open grazed area. Enclosures are an important factor in the protection and vegetation recovery process. Enclosure are effective for rehabilitation if they are well managed. Therefore I would encourage fencing for agricultural purposes, though areas with wildlife might be challenging.

6.2 Recommendations

- County government should discuss the significance of the enclosures with the local residents.
- The county government should conduct a capacity building to seek alternative means of livelihood for the community.
- Reseeding with drought resistant or tolerant herbaceous plants should be considered.
- Documentation to preserve indigenous knowledge in situ and ex situ is needed.
- The results of the present study can be shared with policy makers and agricultural development planners and can be shared during open forums like "barazas" and agricultural events like shows.
- County government to implement water harvesting and conservation.

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APPENDICES

Appendix i: List of some plant species recorded in the study area

	Pokot name	Scientific name /English	Tree	Herb	Grass	Weeds
1	Adomoyon	*Cordia sinensis*	Tree			
2	Akwakwa	*Albizia amara*	Tree			
3	Amatodoyan	not identified				Weeds
4	Boma rhodes	not identified			Grass	
5	Chamangarach	not identified			Grass	
6	Chelwewos	not identified			Grass	
7	Chemoikut	not identified			Grass	
8	Chepiririon	not identified			Grass	
9	Chepkarkalan	not identified				Weeds
10	Chepkatar	not identified	Tree			
11	Chepkopil	*Senna sengueana*	Tree			
12	Chepshashangen	not identified		climber		
13	Cheptukelat	Ficus spp.	Tree			
14	Cheptuya	*Euclea divinorum*	Tree			
15	Chiroi	not identified			Grass	
16	Chuchwen	*Dovyalis macrocalyx*	Tree			
17	Fangeria	*Vangeuria Spp*	Tree			
18	Kaparsamugh	not identified	Tree			
19	Katagh	*Commiphora africana*	Tree			
20	Katasikirio	not identified		Herb		
21	Kelkela	not identified		Herb		
22	Keltama	not identified		climber		
23	Kerelwa	*Croton dichogamus*	Tree			
24	Kinyati	*Ximenia americana*	Tree			
25	Kiswoi	*Solanum nigrum*		Herb		

26	Kolion	*Acokanthera schimperi*	Tree			
27	Kromwo	*Ozoroa insignis*	Tree			
28	Lekatetwo	*Carissa edulis*	Tree			
29	Makongeni	*Agave sisalana*		Sisal		
30	Mamaran	not identified		Forbs		
31	Manampelyon	*Gardenia spp.*	Tree			
32	Manguwan	not identified		climber		
33	Mitoo (Kiswahili)	*orch*		Herb		
34	Mkurian	not identified			Grass	
35	Mokuwo	*Grewia Villosa*	Tree			
36	Multayos	not identified			Grass	
37	Parkinsonia	*Parkinsonia aculeata*	Tree			
38	Pchichin	not identified	Forbs			
39	Ptar	*Acacia brevispica*	Tree			
40	Sangakak	*Faidherbia albida*	Tree			
41	Sekution	not identified			Grass	
42	Senetwo	*Senna didymobtrya*				
43	Sikakout	*Aloe* spp.				
44	Silangwa	*Gourds* plant				
45	Sirwow	*Rhus natalensis*	Tree			
46	Sitot	*Grewia bicolor*	Tree			
47	Stoghon	Acacia brevispica	Tree			
48	Songowo	*Zanthoxilum chalybeum*	Tree			
49	Sukumbu	*Mexican marigold*				Weeds
50	Talamoghion	*Acacia mellifera*		Herb		
51	Tapoyo	*Pilliostigma thonningii*		Tree		
52	Tirokwo	*Zizyphus mucronata*		Tree		
53	Torokwo	*Juniperus procera*		Tree		
54	Tuyunwo	*Balanites aegyptiaca*		Tree		

Appendix ii: Semi-structured questionnaire

1. Where do you graze your animals? OPEN, ENCLOSURES or BOTH
2. If in BOTH which months do you graze in OPEN and in ENCLOSURES?
3. What do you consider when deciding where and when, to graze a certain area?
4. What do you do when land condition is too poor for grazing?
5. Has the range condition change in the last 20 years? Yes No
6. Explain how in question 5 above.
7. What indigenous rangeland management practices used before the introduction of enclosures, that is still in use in the area?
8. Has indigenous knowledge on the rangeland use and protection cascaded to the current generation?
9. What are the advantages of enclosures/ why are people enclosing their land?
10. For those not enclosing their land what are their reasons?
11. What are the types of fences you use in the area?
12. Does the type of enclosure matter?
13. What are the impacts of the emerging changes on land access rights?
14. How does afforestation affect range health?
15. What changes have you noted on livestock in terms of productivity?
16. Has the number of animals per household changed in the last 20 years?
17. How many animals did you used to sell in 1980s' and in the 2000s'?
18. Are there some plants that had disappeared, before the introduction of enclosures but now exists in the restored areas?
19. What type of enclosures do you have in this area? Private or communal or both
20. Are there incidences of conflicts around enclosures?
21. Have households subdivided their enclosures?
22. What soil and water conservation and rain water harvesting do you practice in your enclosure