PRODUCTION SYSTEMS AND OCCURRENCE LEVEL OF URBAN AND PERI-URBAN AGRICULTURE IN NAIROBI COUNTY, KENYA

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Production Systems and Occurrence Level of Urban and Peri-Urban Agriculture in Nairobi County, Kenya

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DECLARATION

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

Signature.. Date..

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This thesis has been submitted for examination with our approval as the university supervisors.

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DEDICATION

This thesis is dedicated to my late dad Hassan Joseck Maranga, my late mum Martina Baranga, my husband Henry Mokua Momanyi, my children Andrew Momanyi Mokua, Joseck Ogendi Mokua and Joanne Martina Mokua for their love, encouragement, endurance and giving me a reason to carry on even during the hard times.

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ABBREVIATIONS / ACRONYMNS

ANOVA	Analysis of variance
ASK	Agricultural Society show of Kenya
CBD	Central business district
CPPS	Closed plant production system
FAO	Food and Agriculture Organization
GDP	Gross domestic product
GIS	Geographic information system
GPS	Global positioning system
JKIA	Jomo Kenyatta International Airport
Kshs	Kenyan shillings
LUTs	Land use types
M	Meters
MDIS	Mobile drip irrigation system
MoA	Ministry of Agriculture
NFT	Nutrient film technique
NIB	National Irrigation Board

RUE	Resource use efficiency
RUFORUM	Regional Universities Forum for Capacity Building in Agriculture
SDI	Subsurface drip irrigation
SE	Standard error (in regard to inferential error bars)
SPSS	Statistical package for social studies
SSA	Sub Saharan Africa
STATA	Software for statistics and data science
UA	Urban agriculture
UK	United Kingdom
ULDI	Ultra-low drip irrigation system
UNDP	United Nations Development Programme
UN-HABITAT	United Nations Human Settlements Programme
UPUA	Urban and Peri-Urban Agriculture
US$	United States of America dollars
WHO	World Health Organization
WUCOLS	Water Use Classification of Landscape Species

DEFINITIONS

ArcGIS Aeronautical Reconnaissance Coverage Geographic Information System.

ArcMap The central application used in ArcGIS. ArcMap is used to display and explore GIS datasets for a study area, where symbols are assigned, and the creation of map layouts for printing or publication. It is also the application that is used to create and edit datasets.

Characterization The process/act of identifying and describing the various types of production systems used by the Nairobi City County urban farmers.

Nairobi County It is also known as Nairobi City County. It is one of the 47 Counties of Kenya. Nairobi is the largest city and capital of Kenya. It consists of nine (9) Sub Counties, namely Kasarani, Kamukunji, Starehe, Makadara, Dagoretti, Lang'ata, Njiru, Embakasi and Westlands. Four of these sub counties (Kamukunji, Starehe, Makadara, and Embakasi) lie within urban areas while the rest are at peri-urban areas of the City County.

Open space Any open piece of land that is undeveloped (has no buildings or other built structures) and is accessible to the public. It includes parks, community gardens, cemeteries, schoolyards, playgrounds, public seating areas, public plazas, vacant lots, etc.

Production Systems These are various crop production technologies unique to urban and peri-urban agriculture.

Urban Agriculture Farming activities (crops and livestock) in and around cities and towns. It is synonymously used with urban and peri-urban agriculture. Urban refers to within cities and towns whereas peri-urban refers to periphery/ around cities and towns.

ABSTRACT

Information on production systems and occurrence level of urban and peri-urban agriculture (UPUA) in Nairobi County is not adequately documented. This study was aimed at determining the type and distribution of UPUA production systems and occurrence level of farming activities along four major network links in Nairobi County. A descriptive research design was used in this study and it involved a field survey. The target population for were the active urban and peri-urban farmers Nairobi County. In phase one (objective 1) of the study, snowballing and purposive sampling methods were used to identify active farmers, guided by the county agricultural officers and the sub county extension officers from ministry of Agriculture, Nairobi County. In phase two (objective 2), purposive sampling was applied in selecting four (4) major network links of Nairobi County with active UPUA farmers. Multistage (branching links) and systematic sampling were used to select data points. Along each network link sampling points were set systematically at 100m intervals for a length of one (1) km. Any farmer doing farming activity at the point or within a radius of 30m and available to give information was interviewed. Where a farmer was absent but there was a farm, observations were made and recorded on the questionnaire. Information gathered during the field survey included the respondents' socio-economic characteristics, land tenure, type of agricultural enterprises practiced, crop production technologies in use, produce consumption patterns, source of water for farming, waste management and farming challenges. Each respondent's farm was mapped with a Global Positioning Systems (GPS) receiver. Ninety five (95) farms for the active farmers in Nairobi County were mapped in phase one. In phase two, 154 farmers were interviewed and 240 observations made on farms that had no farmer present at the data point at time of data collection. Maps of the sampled sites and localities were processed further using ArcGIS software. The data was subjected to descriptive analysis using the Statistical Package for the Social Sciences (SPSS Version 20). General inferences were presented using percentages and proportions. Further tests (Fishers t-tests) were done to determine whether differences were statistically significant between urban and peri-urban areas. All data were analysed at 5% level of significance. Results were presented using tables, pie charts, bar graphs, photographs and maps. The findings showed a significant difference in size of land / space utilized under different crop production technologies. Crop production technologies of open field, multi-storey, micro garden and moist-bed were significantly (*P*=.014) more on land/space which was less than a quarter of an acre (29.2%). Open field technology was the most utilized crop production technology (26.6%) and was significantly (*P*=0.033) more in use at the peri-urban areas. Multi-storey garden was the second popular technology (18%) and more in use in the urban areas. Institutional land constituted the most significant (*P*=0.012) available land (54.2%) and was heavily relied on in the urban areas. Personal land was also available but significantly higher (*P*=0.023) in peri-urban areas (22.6%). The intensity of farming activities generally increased with an increase of distance from access links/centres near the Nairobi CBD area to the further placed (outskirts) access links/centres along three major network links of Nairobi County. Of all the data points,

fifty nine percent (59%) had farming activities going on among the major road transects. Crop enterprises were the major farming activity (slightly over 90%). Fruits (27%) and vegetables (19.9%) were the major crops cultivated. Poultry (38.5%) and cattle (34.6%) were the major livestock found along the 4 major networks in Nairobi County. With the evidence of diminishing agricultural land and increasing of built-up areas, farmers in the city can adopt new and modern space-efficient technologies to continue producing food. This can contribute towards the achievement of some of the sustainable development goals (SDGs) especially on enhancing resilience towards food insecurity and ensuring sustainable lives in urban communities. These findings would act as a supplement to Nairobi city urban planners' decision making process concerning UPUA, land use and space allocation and utilization of resources for increased UPUA. The departments of agriculture and the urban planning need to seek ways for utilizing the institutional land for UA. This can be possible by collaborating with the community members (especially the vulnerable - youth, women, persons with disability and low-income earners)

CHAPTER ONE

INTRODUCTION

1.1 Background information

Urban agriculture (UA) is an umbrella term encompassing agricultural activities conducted in or around a city, town or metropolis (Zezza & Tasciotti, 2010; Eloglu, 2012; Sanye-Menguel *et al*., 2016; Wielemaker *et al*., 2019). Food and Agriculture Organization (FAO) identifies UA as "agriculture practices within and around cities which compete for resources (land, water, energy, labor) that could also serve other purposes to satisfy the requirements of the urban population" (FAO, 2013). The term UA is synonymously used with urban and peri-urban agriculture (UPUA). Urban refers to within cities and towns whereas peri-urban refers to periphery/ around cities and towns. Two hundred (200) million people are employed in urban farming and related enterprises (Zezza & Tasciotti, 2010; Van den Broeck & Kilic, 2019), contributing to the food supply of 800 million urban dwellers (FAO, 2013; Artman & Breuste, 2020). Urban agriculture has direct positive impact on farming households (Lee-Smith, 2013; Joshua *et al*., 2020). It supports main employment through income from sales of surpluses, savings on food expenditures, and exchange of agricultural products for other economic goods (Cofie, 2009; Eloglu, 2012; Kumar *et al*., 2019).

Globally, the growth of cities and urbanized areas continues at an increasing rate. The fastest growth is being experienced in developing countries of the world. The world urban population is estimated to increase from 2.86 billion in 2000 to 4.98 billion by 2030 (UN-HABITAT, 2013; World Bank, 2017). It is acknowledged that as the world's urban population grows, so too does the population of the urban poor (Beall & Fox, 2007; Aerni, 2016). Ravallion *et al*. (2007) and Kuddus *et al*. (2020) estimate that about one-quarter of the developing world's poor live in urban areas. Aerni (2016) reveals that poverty is becoming more urban and the poor are urbanizing faster than the population as a whole.

Rapid urbanization in Sub-Saharan Africa (SSA) has led to serious concerns about household food security in urban areas (Satterthwaite *et al*., 2010; Hove *et al*., 2013; Tuholske *et al*., 2020). Cities appear and grow with the loss of usable farm land and become areas where cement blocks, roads and parking lots dominate the landscape, and where pollution and increase in waste material cause dire concerns (Eloglu, 2012; Fanzo, 2012). Urban agriculture has been recognized as serving an important role in the economic, social, and dietary life of many cities in Sub-Saharan Africa (Satterthwaite *et al*., 2010; Schmidt, 2011; Lee-Smith, 2013; Stewart *et al*., 2013; Conceição *et al*., 2016).

Kenya has during the last four decades, witnessed rapid rate of urbanisation estimated at 6 percent (UN, 2011). This growth is spurred by the perceived better opportunities in the urban centres as opposed to increasing incidences of poverty and insecurity in the rural areas (UN, 2011; Ecotact, 2011; Owuor, 2019). The proportion of those living in the urban areas has risen from 8 percent as at independence to 34 percent (UN-HABITAT, 2006; FAO, 2010; Ecotact, 2011). It is projected that over 50 percent of the national population will be living in the urban areas by the year 2025 (FAO, 2010; Ecotact, 2011).

Nairobi County had the largest urban population of 3,138,369 people by the year 2009 (KNBS, 2010) and was projected to rise to 5,433,002 by the year 2020 (Mwaura *et al*., 2019). The population rose to over four million according to KNBS (2019). Thirty percent of these residents practise urban agriculture majorly as a livelihood strategy (Karanja *et al*., 2010; Kaluli *et al*., 2011; Lee-Smith, 2013). Confronted with rapid urbanization, thousands of families strive to “improve their access to food and raise income through agricultural activities in urban and peri-urban areas” (Karanja *et al.*, 2010; Lee-Smith, 2013; Mwaura *et al*., 2019; Mwangi & Crewett, 2019). Urban farming is generally practiced for income-earning or food-producing activities (Table 1.1), though in some communities the main impetus is recreation and relaxation (Fasla, 2010; Lohrberg, 2019; Popović & Mihailović, 2020).

Table 1.1: Urban agriculture contribution to Nairobi County's nutritional self-reliance and economy (Source: Ministry of Agriculture (MoA), 2015)

Year	2012		2013		2014	
Produce type	Quantity	Value (000Kshs)	Quantity	Value (000Kshs)	Quantity	Value (000Kshs)
Tomato (in metric tons)	-	-	606	15,120,000	479.60	132, 380
Sweet potatoes (in tons)	249	-	147	-	175	-
Beans (in 90kg bag)	5,945	-	14,856	-	13,700	-
Eggs (trays)	17,791,884	-	1,439,332	-	1,626,006	-
Milk (kg)	41,479,967	-	39,486,340	-	38,762,174	-
Aquaculture (in metric tons)	288	62,021	311	72,034	645	152,399
Rabbits (number)	-	-	40,274	-	42,610	-

1.1.1 Environmental Benefits of UPUA

Apart from direct economic impact, there are also indirect social benefits that are derived from the economic gains, such as the possibility to pay school fees, acquire more household and farm assets and pay for better health care and livelihoods support (FAO, 2013; Othman *et al*., 2018). Urban agriculture is important in environmental management. The link between UA and environmental sanitation is highly significant both for positive and negative reasons (Cofie *et al*., 2008). On the positive side, in addition to supplementing rural agriculture in food supply, UA creates an avenue for recycling readily available urban organic wastes, thereby improving the productivity of farming systems as well as environmental health. Urban agriculture facilitates the recycling of waste such as poultry manure, cow dung, market/household waste, human waste etc. (Cofie, *et al*., 2008; Cofie, 2009; Ulm *et al*., 2019).

On the negative side, inappropriate husbandry of UA poses negative environmental impacts such as contamination of local water sources, especially if large amounts of chemical fertilizers and pesticides are used. Also, the excessive use of nitrate-rich manure, such as chicken or pig manure can contaminate groundwater. In particular, wastewater discharge from intensive poultry farms can carry heavy loads of micro-organisms and may contaminate drinking water supplies. Further, under certain situations, inappropriate farming practices may lead to reduction of vegetation and siltation of water bodies (Qasim *et al*., 2017; Zegeye, 2017; Iori *et al*., 2019). Some UPUA farmers in Nairobi, Ouagadougou and Dakar use wastewater directly from city sewage for agriculture. This is an informal irrigation which poses a potential health threat such as bacteriological contamination (Cofie & Drechsel, 2007; Dickin *et al*., 2016; Woldetsadik *et al*., 2017a; Woldetsadik *et al*., 2017b; Jongman & Korsten, 2018; Abass *et al*., 2019).

1.1.2 Poverty and Urban Food Security

National statistics show that out of forty seven (47) counties, Nairobi County had the largest urban population with 3,138,369 people in 2009 (KNBS, 2012c) and was ranked position two (2) in poverty with a poverty rate of 22.5 percent. Ten years later, the population, grew to over four million people (KNBS, 2019). The city of Nairobi equally is going through the urbanization challenges including the provision of food, water and sanitation especially in slum areas where majority of the urban poor are living. Between a third and half of the country's urban population live in poverty, and given the pace of urbanization, urban poverty will represent almost half of the total poverty in Kenya by 2020 (Mutisya & Yarime, 2011; Ruel *et al*., 2017; Shifa & Leibbrandt, 2017; Lucci *et al*., 2018). Moreover, while urban poverty has been decreasing according to some measures, statistics indicate that the proportion of the urban population that is poorest of all (the 'food poor' and 'hardcore poor') has been on the rise (Rudolph & Kroll, 2016; Ruel *et al*., 2017a; Ruel *et al*., 2017b).

1.2 Statement of the Problem

The rapid global urban population growth has put pressure on food demands causing food insecurity. This is highly felt on developing nations of the world. Despite continued economic growth around the world, food insecurity remains a pressing problem in many parts of Africa. Cities in Sub-Saharan Africa (SSA) are growing at an exceptional rate of about 5 percent annually (Saghir & Santoro, 2018). The UN-HABITAT (2006) reports that the percentage of urban residents in SSA is expected to rise from 30 to 47 percent of the total population during the period lasting from 2005 to 2030. The rate is expected to rise and urban issues will continue to rise to threaten populations, restrain urban food security and endanger urban ecosystems. This will bring about new and critical challenges for urban development policy, especially in terms of ensuring household food security. There is urgent need to question the current status of cities in regard to available food systems, and it is necessary to search for new methods to alleviate the current conditions (Eloglu, 2012; UN, 2012). The Kenya Population and Housing Census results released in August 2019 revealed that Kenya's population had risen by ten million people since the last count in 2009, an average of one million people per year (KNBS, 2019). This is likely to trigger unprecedented challenges given that already the capacity of the local authorities to cope with the rapid population growth has been overstretched (Ecotact, 2011).

Urban and peri-urban agriculture is often undervalued and faced with stiff competition from other urban land uses such as construction of residential and commercial buildings. In Nairobi County, the spaces for UA are not well recognized as a legitimate land use and therefore, the security of tenure becomes a constraint to legal and safe practice of urban agriculture (Agarwal & Sinha, 2017; Dominati *et al*., 2019). Urban agriculture has potential to make cities such as Nairobi more socially and ecologically sustainable, but urban planners have not had effective policy levers to encourage this (Mendes *et al*., 2008; Lubell *et al*., 2009; Bricas *et al*., 2019; Halliday, 2019).

Though some of urban dwellers of Nairobi City County practice some form of agriculture to provide food for themselves and their families, there is need to question the current status of the city, in regard to available food systems (FAO, 2013; Wascher *et al*., 2017; Onono *et al*., 2018). Little is known on both the type of production technologies utilized by UPUA farmers and the distribution of UPUA farm enterprises in Nairobi County. Reliable data on the extent of urban/peri-urban areas being used for farming in Nairobi County, the spatial distribution of such areas, type of crops, animals and proximity to market places are lacking (Revi & Rosenzweig, 2013; Tilman *et al*., 2017; Robineau & Dugué, 2018; Smidt *et al*., 2018). This can partly be attributed to the fact that ground-based survey methods for data capture for detecting and measuring change are relatively expensive and time consuming.

1.3 Objectives

1.3.1 General Objective

To determine characteristics of production systems and occurrence level of urban and peri-urban agriculture in Nairobi City County, Kenya.

1.3.2 Specific Objectives

1. To determine the distribution and constitution of urban and peri-urban agriculture production systems in Nairobi City County, Kenya.
2. To determine occurrence level and nature of farming activities across four major networks of Nairobi City County.

1.4 Research Questions

i. How are the crop production technologies distributed and constituted within urban and peri-urban areas of Nairobi City County?

ii. What is the occurrence level and nature of farming activities across major transect links of Nairobi City County?

1.5 Justification

The growing population in the city need food, which is a major concern to the government. Food systems are getting more globally entangled leaving consumers at the mercy of markets and conventional products (Wang & Wang, 2008). The practice of UPUA is one way the urban dwellers, especially the urban poor ensure that they are food secure. Urban agriculture attracts more attention and offers new opportunities to urban residents to handle their food systems (Satterthwaite *et al.*, 2010; Hara *et al*., 2018). With its ability to secure food for populations, generate income, sustain urban ecosystems and create livable communities, urban agriculture is praised increasingly in different parts of the world. Also, urban residents are increasingly warming up to their chance of obtaining their right to food (Satterthwaite *et al*, 2010; Yilmaz *et al*., 2016). The city dwellers are able to access a variety of nutritious and fresh food from livestock and crops produce.

Urban planners are increasingly interested in agriculture within and around cities and have to decide whether to maintain or not areas for agricultural land use within and close to growing cities (Aubry *et al*., 2012; Recasens *et al*., 2016; Martellozzo *et al*., 2018).The ability of urban farming to continuously supply food for the urban poor, especially in developing nations, will depend on better planning to enable sustainable management of the practice. Burton and Pires (2012) argue that for UA to play a greater role in supplying urban needs "it must be recognized as a legitimate urban land use activity within city planning regimes, for urban land use planning can only encourage and support activities that are recognized". Urban planning is however not renowned for recognizing UA as a land use, and various studies suggest that formal recognition is paramount for development of urban agriculture (Adam, 2020; Mumenthaler *et al*., 2020; Sturiale *et al*., 2020). FAO (2012) presents recorded cases of Rosario and Cuba showing how UA policies can be developed with enough ability to allow for their evolution from one desired outcome (e.g. response to crisis such as food shortage triggered by various factors) to a more systematic and regular practice once a crisis period is over. This approach reinforces the importance of ensuring that decisions about the type and scale of UPUA policies and interventions adopted are matched with desired outcomes, contributions to the UA sector, and to overall development goals.

In Nairobi City County, the Local Government Act (cap 265) section 155 (b and c) allows some farming of both livestock and crops in the city to curb hunger. However, in the same Act section 144 (c) and Public Health Act (cap 242) section 157 (I) prohibits any form of UPUA in the city leading to creation of bylaws that led to harassment of city farmers. But there has been a total change of events since 2010, whereby authorities started to embrace UPUA. Measures are being put in place to regulate the practice. Urban Areas and Cities Act No.13 (2011) calls for UPUA to be supported and regulated. Urban Agriculture Promotions and Regulations Act (2015) is also in full support for UPUA. Policies in support of UPUA are being formulated and reviewed. One of them is Nairobi City County Urban and Peri-urban Agriculture, Livestock and Fisheries Policy (2015). All these are working towards supporting UPUA so as to create employment, reduce poverty, improve household nutrition and gain supplemental income from sales. This depends on the available information from research work to aid in proper decision making.

Despite pressure from various competing land uses within the urban environment, agriculture continues to be prevalent in most sub-Saharan cities, Nairobi inclusive. It is practised by all economic classes but for low income level city dwellers, as a livelihood strategy. For instance, in Nairobi city, 44 percent of the respondents who rented land for UA were in the urban area compared to 13 percent in the peri-urban area (Pasquini *et al.*, 2009). A partially diversified approach on characteristics and distribution of production systems will enable better understanding of constraining variables in various locations. This will help to recognize how specific technologies can fit into Nairobi urban complexity and provide sustainable socio-economic opportunity within the urban food systems. This research provides useful information especially to policymakers in Nairobi

County that may help with their decision making process concerning urban and peri-urban agriculture in regard to land use allocation. This will aggrandize future research and contribute to the development of suitable policies for urban farming that will play a crucial role towards improved livelihoods of the urban poor. Urban farmers cultivate a wide range of crops and rear a large number of livestock with substantial yields.

1.6 Scope

This study targeted the active farmers of urban and peri-urban areas of Nairobi County. For this research, an active farmer was considered to be the one fully engaged in farming activities as the main occupation, irrespective of whether it is in small or large scale. The study was conducted in 2013/2014 and 2017.covering eight (8) Sub Counties and four (4) major network links of Nairobi City County. The variables assessed were: gender, age bracket, education level, main occupation, income from farming, source of irrigation water, land/space size and ownership, consumption pattern of farm produce and main challenges affecting farming activities.

1.7 Limitations

The study faced prejudice from some of the respondents who thought we had gone to destroy their crops. The agricultural officers from department of agriculture, helped in explaining how agriculture in the city is now being more embraced and that there will be no more harassment. During face to face interviews, we faced language barrier from some respondents but we sought for translators. We took longer time to get one questionnaire answered and as a result fewer than planned interviews could be conducted in a specific period of time.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This contains two sections. Section 2.2 provides a review of the literature of the study. Subsection 2.2.1 focuses on crop production technologies. It brings out examples of use of some crop production technologies both in developed and developing countries. Subsection 2.2.2 has information on extent and locations of urban and peri-urban agriculture. It shows farming in formalized locations to unscheduled/informal land/ spaces such as roadside reserves. This gives a picture of how farmers are ingenious in creating means of survival in otherwise difficult scenarios in places where UPUA is marginalized. Section 2.3 points out the research gaps this study is filling.

2.2 Urbanization and Urban Agriculture

The world is facing urbanization at full speed (Doytsher *et al*., 2010; Eloglu, 2012). Urban (and peri-urban) agriculture has been in existence since time immemorial and continues to grow exponentially with the increase of urban population. Today, it is expected that more than 800 million people are practicing some type of UA in or close to an urban setting providing food for themselves and their families (FAO, 2013; Artmann & Breuste, 2020). Drescher, *et al.* (2008) argues that UA practices not only consist of gardening and horticultural activities, but also they include animal husbandry, food gathering and even hunting. Urban agriculture offers a holistic solution to issues experienced in cities (FAO, 2011; Eloglu, 2012). It gives residents the chance to grow their own food and therefore to grasp their right to food security, generate incomes and it provides the means for creating a sustainable and greener cityscape (Kwon *et al*., 2020; Binns & Nel, 2020). Urban agriculture practices also help to re-establish people's connection to land, and help community development, and beyond that, maintain self-sufficiency (Eloglu, 2012).

Urban and peri-urban agriculture can play a crucial role in the economy, social and dietary life of urban dwellers, more especially the urban poor (Lee-Smith, 2013; Ogendi *et al*., 2019). Urban agriculture becomes therefore an indispensable agenda for cities that are in urgent need to adjust their dynamics in regard to global and local developments about food and agriculture (Frayne *et al*., 2009; Appolloni *et al*., 2020; Arshad & Routray, 2020; Luehr *et al*., 2020; Rufí-Salís *et al*., 2020).

2.2.1 Production Systems in the Urban and Peri-urban Areas

Urban agriculture has taken several production systems. It is carried out on the standard ground level farm or garden, which is either on communal land or on private property (Eloglu, 2012; Camara, 2013; Goodman & Minner, 2019; Weidner *et al*., 2019; Artmann & Breuste, 2020). Production systems range from agricultural and horticultural crops to forestry, floriculture, aquaculture and livestock production (Ambrose-Oji, 2009; Liang *et al*., 2019; Ayambire *et al*., 2019). Open field production technology in most cases is a full-time job for many poor people. Plots in open spaces used for UA include backyard plots, community gardens, institutional gardens, roadsides, airport buffer zones, along drainage systems, middle of roundabout, parks, under power lines, along and between railway lines, among others. Unseen directly from the city are the intensive-irrigated plots and fields in urban fringe (Ambrose-Oji, 2009; Mwangi & Crewett, 2019). A review of profits from vegetable production in open-space urban agriculture shows that monthly income can go up to US$ 330 especially if there is large area, extra labor and available water for irrigation (Cofie, 2009).

Citing Dubbeling (2011), Specht *et al*. (2014) state that ‘no-space or low-space technologies offer tremendous opportunities for space-confined growing’. Multi-storey gardening, a crop production technology also known as vertical gardening is practised in some parts of Nairobi City County (Ogendi *et al*., 2019). Gallaher *et al*. (2013b) state that vertical gardening allows households of Kibera slums of Nairobi city to take advantage of small open spaces to grow food by planting ’20-30 plants of kales and spinach onto sides and tops of a 50kg sack of soil'. The vertical garden structure is useful for safe growing of the selected vegetable requirement of a family and can be accommodated in sunlit utility area, balcony and terrace (Rathinakumari *et al*., 2019). Its structure has three major sub structure viz., (i) base frame, (ii) main central support and (iii) supports for pots/grow bags. Pots suitable for growing different vegetables, flowers and medicinal plants can be used with soil or soilless (cocopeat) growing medium (Rathinakumari *et al*., 2019). According to Gallaher *et al*. (2013a), this type of gardening has a positive impact on household food security in Kibera, 'strengthening social capital amongst farmers'.

Sky farming (an application method of green building) represents a promising approach for food production that is largely environment independent and therefore immune to climate change. It uses vertical landscape system (Plate 2.1) in order to realizing food self-sufficient green city (Troskie, 2011; Germer *et al*., 2011; Putri *et al*., 2016). Optimal growing conditions, shielded from weather extremes and pests are aimed at raising plant production towards physiological potential (Germer *et al*., 2011). The planting system is done by applying hydroponic plants with *Nutrient Film Technique* (NFT) using energy source of solar cell and grey water from the processing of waste treatment plant. The application of sky farming in urban areas can be a recommendation for the design of environmental-friendly construction (Bernhardt, 2010; Troskie, 2011; Graff, 2012; Putri *et al*., 2016; Butturini & Marcelis, 2020).

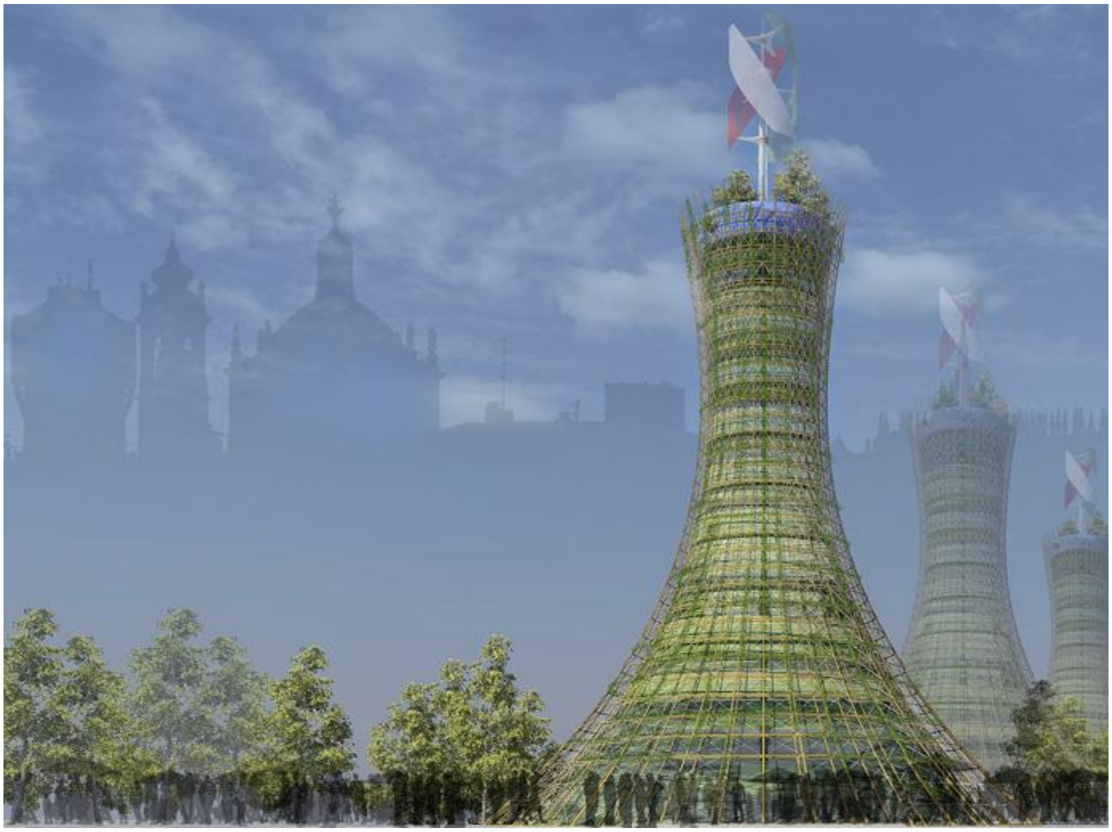

Plate 2.1: Example of Sky farming system in London City, UK. (Source: https://www.rsh-p.com/projects/skyfarm/)

Zero acreage farming (zfarming) refers to urban agricultural production technologies such as rooftop gardens, rooftop greenhouses, edible walls and indoor farms. These are farming activities done inside or on top of buildings to address challenges of scarce land for farming in cities (Specht *et al*., 2014; Sanyé-Mengual *et al*., 2016; Ercilla-Montserrat *et al*., 2019;). FAO (2013) advocates focussing on urban food systems that can address malnutrition and narrates how innovations in technology for agriculture can open up opportunities for users to earn higher incomes which can be used for added attention to their family needs such as supplemental food, clothing, rent and school fees. Specht *et al*. (2014) state that urban rooftop gardens in developing countries practised on small scale contribute to welfare of poor urban residents by supplementing their diet, family income and reduce expenditure on food to allow other purchases. Eloglu (2012) noted that UA is a creative activity in the city as it trains the practicing residents to be food secure even when they have no access to farming land.

Micro-gardening is the intensive cultivation of a wide range of roots and tubers, vegetables and herbs in small spaces, such as rooftops, patios and balconies (FAO, 2010). While urban residents have long grown vegetables in backyard plots, modern micro-gardening makes use of containers such as custom-built tables, plastic lined wooden crates and even old car tyres. This method integrates horticulture production techniques with environmentally friendly technologies suited to cities, such as household waste management and rainwater harvesting. Micro-gardens allow low-income families to meet their needs for vitamins, minerals and plant protein by providing direct access to fresh, nutritious vegetables every day. They also offer a source of extra income from the sale of small surpluses (FAO, 2010). Studies reveal that micro-gardening can improve food security, economic resilience and help to achieve sustainable development as it is a survival strategy for the vulnerable urban residents (Dehnavi & Süß, 2019; Andal, 2021).

Increasing concerns about water scarcity have promoted the adoption and diffusion of irrigation technologies such as drip irrigation, which allow farmers to use water in a more efficient way, while saving water resources (Venot, 2017; Alcon *et al*., 2019). The other modern pressurized irrigation systems that maximize water saving include gun irrigation, center pivot irrigation (Plate 2.2) and linear irrigation systems (Neissi *et al*., 2020). Drip irrigation delivers water directly to the roots of plants in just the right amounts through porous or perforated tubing installed on or below the soil surface (Fig 2.1). Compared with conventional flood or furrow irrigation, drip methods can reduce the volume of water applied to fields by up to 70 percent, while increasing crop yields by 20-90 percent and it appears to be taking off worldwide (Zwarteveen, 2017; Hossain *et al*., 2017). Modern drip methods are sometimes classified into ultra-low drip irrigation (ULDI) system and mobile drip irrigation system [MDIS] (Fayed, 2020).

Drip-irrigated area now totals over 10.3 million hectares across the world (Birkenholtz, 2017). Most of this growth has occurred in the arid and semi-arid regions of the United States, India and China, where there is often a primary reliance on groundwater for irrigation and drinking water needs (Birkenholtz, 2017). In UPUA, subsurface drip irrigation [SDI], (Fig 2.2) is the major modern irrigation method which is part of smart irrigation techniques (Canales-Ide *et al*., 2019; Dalla Marta *et al*., 2019). Under the SDI, plant water requirements are estimated using the Water Use Classification of Landscape Species (WUCOLS) III method, in which plant water requirements are based on the composite of plant species and not on a single species, as in the case for classical crop coefficients (Canales-Ide *et al*., 2019).

Plate 2.2: Center pivot irrigation system at Galana Kulalu Irrigation Scheme (National Irrigation Board), Kenya (source: author, 2015)

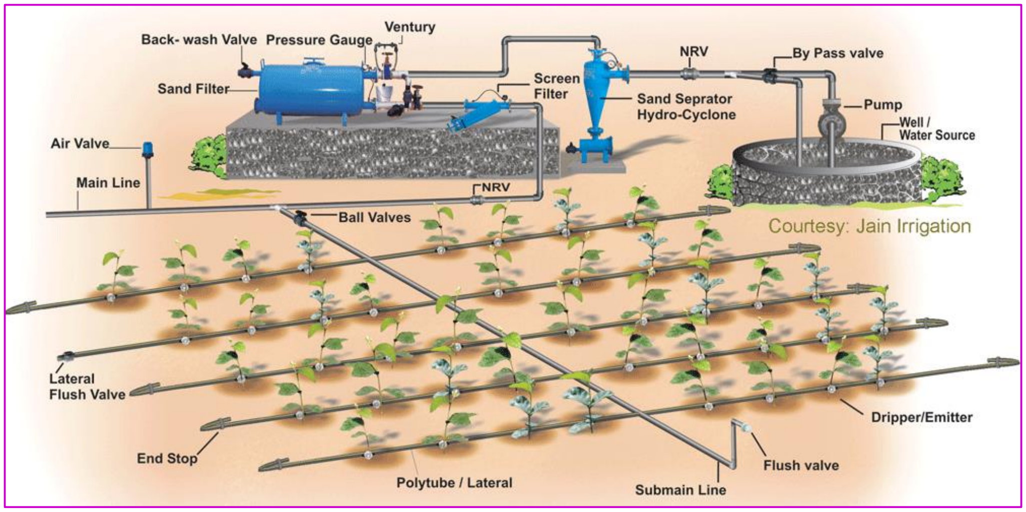

Figure 2.1: Example of layout of drip irrigation system and its parts (source: www.wikipedia.org)

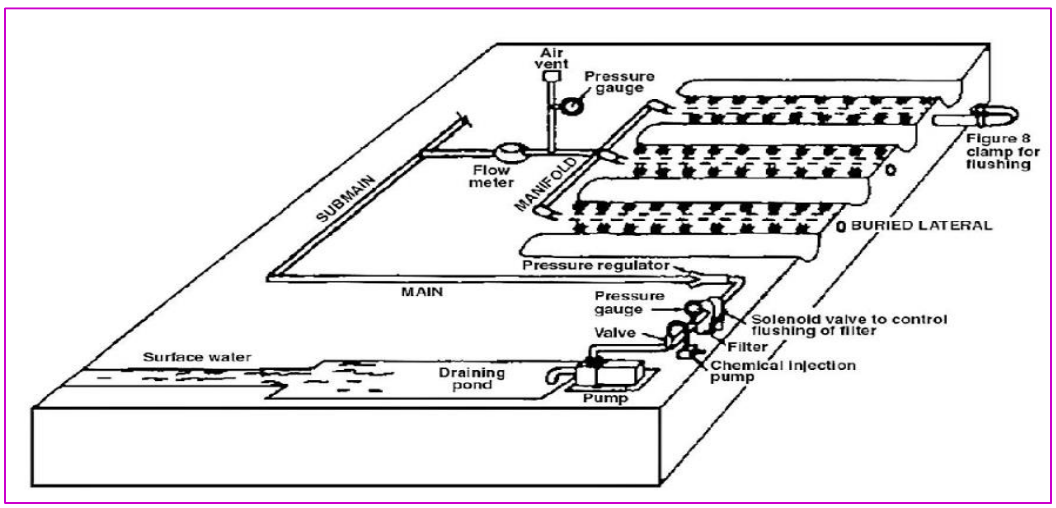

Figure 2.2: Example of layout of subsurface drip irrigation system and its parts (source: Reich et al., 2009)

Some other emerging technologies such as soil-less agriculture (aquaponics, hydroponics, and aeroponics) may also have specific niches in UPUA (Lal, 2013; Orsini *et al*., 2013). Aquaponic is a production system for integrating aquaculture with hydroponic vegetable crops that can play a crucial role in the future of environmental and socio-economic sustainability in smart cities (Dos Santos, 2016). Urban hydroponics (Plate 2.3) especially on industrial rooftops will supply doorstep year round diversified and healthy fresh fruits and vegetables without long transportation chains, adding income opportunities for the poorer population (Schnitzler, 2012; Haberman *et al*., 2014). Hydroponic systems have been a great success in Europe (Romeo *et al*., 2018) and their performance has been better than heated greenhouses.

More advanced modern technologies for crops in UPUA include closed plant production system (CPPS). The CPPS system (Plate 2.4; Fig 2.3) consists of a thermally insulated and airtight structure, a multi-tier system with lighting devices, air conditioners and fans, a CO_2 supply unit, a nutrient solution supply unit, and an environment control unit (Kozai *et al*., 2004; Kozai, 2013; Kozai, 2016). The CPPS has been used for the production of vegetables, fruits, medicinal plants and genetically modified crops for pharmaceutical use (Genovese *et al*., 2008; Goto, 2012; Kozai, 2013). The advantages of CPPS include rapid and uniform growth of high quality plants, high productivity per floor area partly due to the use of multi-shelves, and use efficiencies of water, CO_2 and light energy are considerably higher in the CPPS than in a greenhouse (Kozai *et al*., 2005; Kozai & Niu, 2016).

Plate 2.3: Example of hydroponic system for growing crops such as lettuce in UPUA (source: Kozai, 2013)

Plate 2.4: Example of closed plant production system (source: Kozai, 2013)

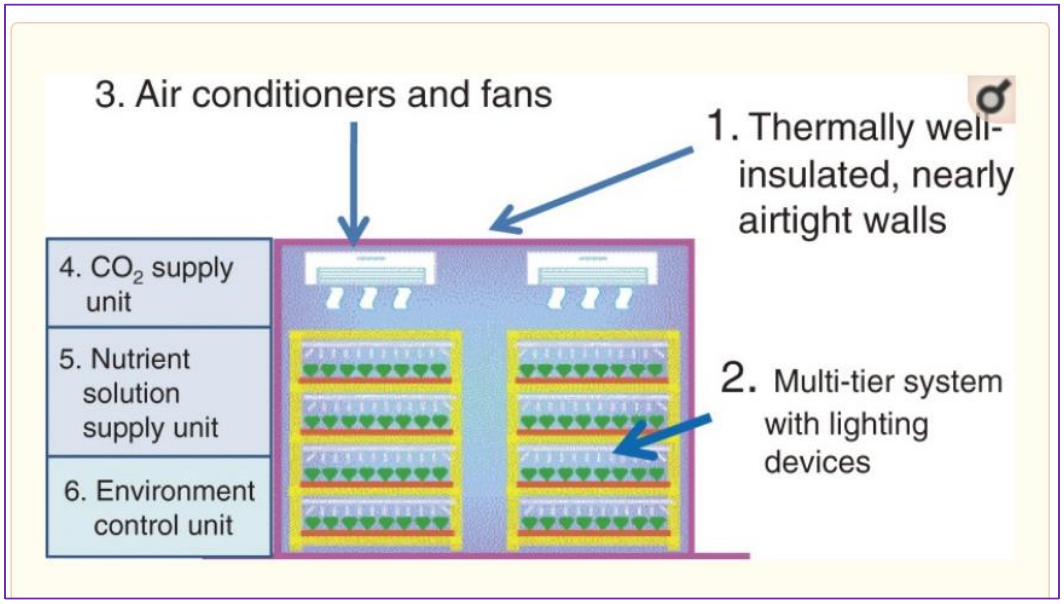

Figure 2.3: Configuration of the closed plant production system (source: Kozai, 2013)

2.2.2 Occurrence of urban and peri-urban agriculture

Farming activities in the urban and peri-urban areas tend to vary depending on the characteristics of available land and spaces. The practice can be found in locations such as, "small community gardens", personally managed allotments, home gardens, portions of parks that were previously planted entirely with amenity species and fruits trees along roadside reserves (Pearson, 2010). Urban and peri-urban agriculture is also done on undeveloped land, river reserves, abandoned waste dumps, rights-of-way and aircraft buffers (Cofie *et al*., 2008). According to Schmidt (2012), rapid growth and constant pressure on land for development has forced urban and peri-urban farmers to encroach on open spaces and other public lands such as cemeteries, playgrounds, roadsides and utility rights-of-way. Cultivating communal as opposed to privately-owned land, has been advantageous because in dense cities, most people do not have access to their own parcel of land (UN-HABITAT, 2008). There is also often a deep and positive sense of community that can thrive in a communal situation, especially with an activity enjoyed across age groups, cultures, and income level (Gittleman, 2009). The variation of occurrence of farming activities also depends on the characteristics of the urban setting defined by geography and climate along with the abilities of the urban populations in terms of reaching and creating resources (Appolloni *et al*., 2020; Skar *et al*., 2020).

Other locations utilized for UA are parks, along drainage /sewage system, in the middle of roundabouts, damping sites, under power lines, airport buffer zones and along and between railway lines (Bousbaine *et al.*, 2020). These areas are open to full spectrum of the societal activities and their sound planning and design make them more attractive. Besides important environmental benefits, these areas provide social psychological services, which are critical for the livability of the city and well-being of urbanites (Arshad& Routray, 2020). With only limited spaces to appreciate and practice agriculture, urban residents find themselves more and more surrounded by a food system dependent on outside food sources (Goss, 2011; Eloglu, 2012; Blekking *et al*., 2020). The distance to areas of food production also necessitate consumption of processed food causing urban residents to remain uninformed about where and how food in their plates is produced and processed (Eloglu, 2012; Lipinski, 2013; Khandpur *et al*., 2020; Battersby and Hunter-Adams, 2020; Turkkan, 2020).

2.3 Research Gaps

From various literature reviews conducted, city farmers in various parts of the world are overcoming shortage of land for farming by embracing production technologies and ingeniously using any available resources to sustain urban and peri-urban agriculture. The farmers of Nairobi County are constantly being displaced from their farming spaces to pave way for other land uses. The development projects that have replaced arable land in Nairobi city include construction and expansion of roads (such as Mombasa road and Thika Superhighway), railway, power lines, commercial and residential buildings These famers are forced to find ingenious ways of going on with their urban farming activities. Some urban and peri-urban production technologies had been introduced to the farmers through the ministry of agriculture and NGOs. However, no research had been conducted to determine the adoption and distribution of the technologies. Also no research had been done on the intensity of farming activities in the city.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter contain subsections which give detailed information on the research design, target population, sampling procedure, sample size, data collection, processing and analysis for the study.

3.2 Research Design

A descriptive research design was used in this study and it involved a field survey. This design was preferred because the area of study was large (a whole county) and it had individual people as a unit of analysis. The study sought to provide information concerning farming activities carried in and around Nairobi city.

3.3 Study Site

This study was conducted in Nairobi County. Nairobi, the capital city of Kenya, covers an area of about 696 km². The city is bounded within geographic coordinates of 1°16'S latitude and 36°48'E longitude. At the time of study, Nairobi County had nine (9) sub counties (Fig. 3.1). The urban sub counties were Starehe, Makadara, Embakasi and Kamukunji. The peri- urban sub counties were Kasarani, Westlands, Dagoretti, Lang'ata and Njiru (Ogendi *et al*., 2019). At between 1600 and 1800 metres above sea level (Rateng, 2019; Ogega *et al*., 2019), Nairobi enjoys a moderate climate. Under the Köppen climate classification, Nairobi has a subtropical highland climate. There are two rainy seasons, with long rains falling between March and May and short rains between October and December. Annual rainfall ranges between 300mm and 700mm (Wangari, 2013). Since Nairobi is situated close to the equator, the differences between the wet and dry seasons are minimal and the timing of sunrise and sunset varies little throughout the year.

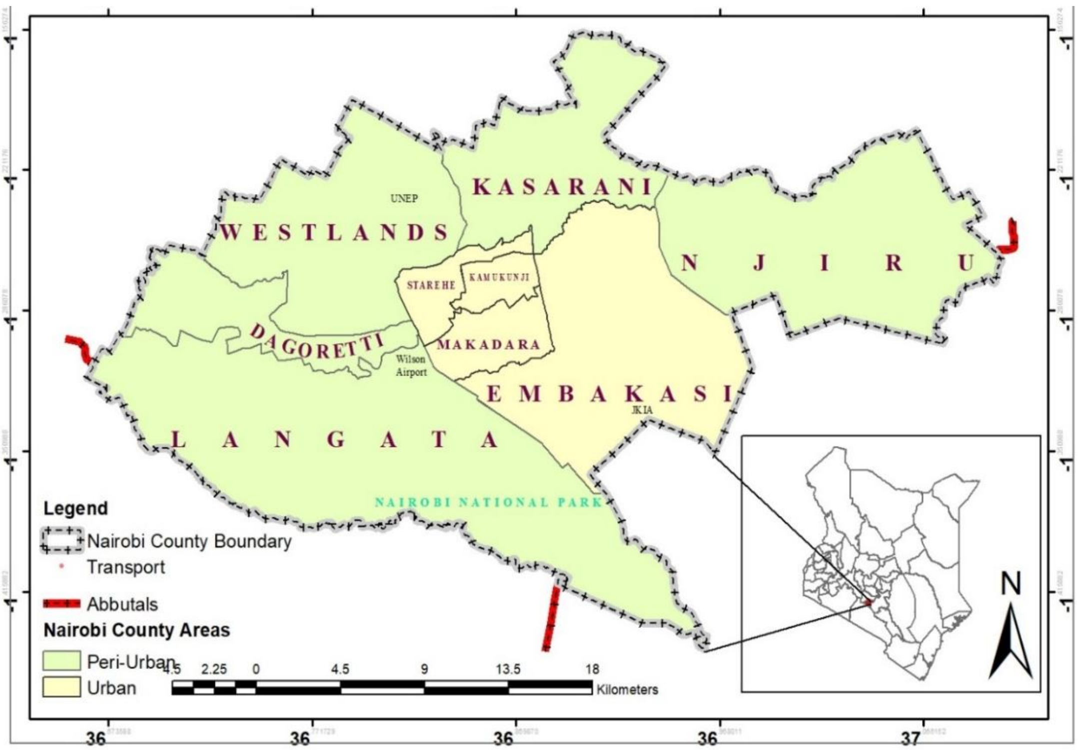

Figure 3. 1: Map of study area showing urban (Starehe, Kamukunji, Makadara and Embakasi) and peri-urban (Njiru, Kasarani, Westlands, Dagoretti and Lang'ata) Sub Counties of Nairobi County. (Source: Ogendi *et al*., 2019).

3.4 Target Population

The urban population of Nairobi city has been growing rapidly. Nairobi County had an estimated population of 3,138,369 people and 985,000 households by the year 2009 (KNBS, 2010) and 4,337,080 people by the year 2019 (KNBS, 2019). The population growth rate of Nairobi is about 4.1 percent per annum, however about 60 percent of this population are described as urban poor and live in informal settlements (Mutisya and Yarime, 2011). The target population for this study were the active urban and peri-urban farmers Nairobi County. The active farmers were purposefully identified by the help of county agricultural officers and the sub county extension officers from Ministry of Agriculture, Nairobi County. The Ministry of Agriculture officers said to have an estimated 200,000 households involved in urban and peri-urban agriculture farming in Nairobi County. The farmers of Nairobi County are involved in various farming activities ranging from raring of livestock to growing of various crop categories including flower nurseries which are usually placed along roadsides to attract market. Mixed farming is the most preferred practice. The farming activities are not limited to low income earners only who practice it as a livelihood strategy. Middle and high income earners also do practice farming both as a leisure activity and for fresh and safe crop products for their household. The farming activities are usually for home consumption to supplement their diet, though some farmers sell the surplus to earn income. The sales mostly occur at farm gate, customers being the neighbors and local markets. Apart from farming, a majority of the Nairobi County farmers are occupied in other services such as business, studies, formal and informal employment.

3.5 Sampling Procedure and Sample Size

In phase 1 (objective 1) of the study, snowballing and purposive sampling methods were used to identify active farmers, guided by the county agricultural officers and the sub county extension officers from ministry of Agriculture, Nairobi City County. Also farmers led us to other farmers. In phase 2 (objective 2), purposive sampling was applied in selecting 4 major network links of Nairobi City County with active UPUA farmers. Multistage (branching links) and systematic sampling were used to select data points. Along each network link sampling points were set systematically at 100m intervals for a length of 1km. Any farmer found doing farming activity at the point or within a radius of 30m and willing to give information was interviewed. Where a farmer was absent but there was a farm, observations were made and recorded on the questionnaire. Thika superhighway, Mombasa road, Ngong road, and Waiyaki way were identified as the four major network links that transect Nairobi City County and dissect it into four (4) quarters. Sampling was conducted along these links and along their main access points (access roads). These methods helped a great deal as some farmers were far from each other and some communities were gated and hesitant to be interviewed. Given an estimation of

200,000 active farmers, Naissiuma's formula was used to calculate the sample size: n= $\frac{NCv^2}{(CV^2 + (N-1)e^2)}$

Where N=Population, CV=Coefficient of variation (0.5), n=sample size

e=Tolerance of desired level of confidence (take 0.05% at 95%confidence level)

N being 200,000 persons hence, $n = \frac{200000\ (0.5)^2}{0.5^2 + (200000-1)0.05^2}$

n = 100.

The sample size = 100 respondents.

3.6 Data collection

Trained enumerators accompanied with the research student (me) were involved in data collection. Pretesting of the questionnaire was done to a sample of 15 participants to ensure the questions are vividly articulated, relevant and necessary. Revisions were done accordingly. Pilot testing was also done to increase the success of the main study. Face-to-face interviews were conducted and respondents could ask for clarification of questions during the session. Field observations through recording of the information on the preset data sheet were done to collect any unique feature or information. Information like type of crop or livestock was noted by looking around the farm without necessarily asking the farmer. Semi-structured questionnaires were administered. A Global Positioning Systems (GPS) receiver (Garmin model Etrex 10) was used to map respondents' farms during the field survey. The information gathered during the field survey included the respondents' socio-economic characteristics, land tenure, type of agricultural enterprises practised, crop production technologies in use, consumption patterns, source of water for farming, waste management (crop, livestock and water), farming challenges, farmer's perception on public open space and farmer-urban planners relationship in regard to urban and peri-urban agriculture.

Ninety five (95) farms for the active farmers in Nairobi County were mapped in phase one (Fig.3.2). Fifty five (55) and forty (40) farms were mapped in the peri-urban and urban areas, respectively. The urban area mapped farms included Kamukunji (13), Starehe (11), Makadara (8) and Embakasi (8).The peri-urban area mapped farms included Kasarani (16), Njiru (15), Dagoretti (12) and Westlands (12). In phase two for objective 2, 672 data points were visited and mapped (Fig.3.3) on four road transects. Mombasa road had (269), Ngong road (215), Thika road (117) and Waiyaki Way (71) data points. 394 data points of the total had farming activities going on (154 farmers were interviewed and 240 observations made). These 240 observations were made on farms that had no farmer present at the data point for the interview at time of data collection. In total, 249 (95+154) farmers were interviewed and 489 (95+394) farms were visited for this study. These areas comprised of residents ranging from sparsely populated high income levels like Kileleshwa Estate in Westlands sub county to densely populated low income levels like Kiambio slums in Kamukunji Sub county.

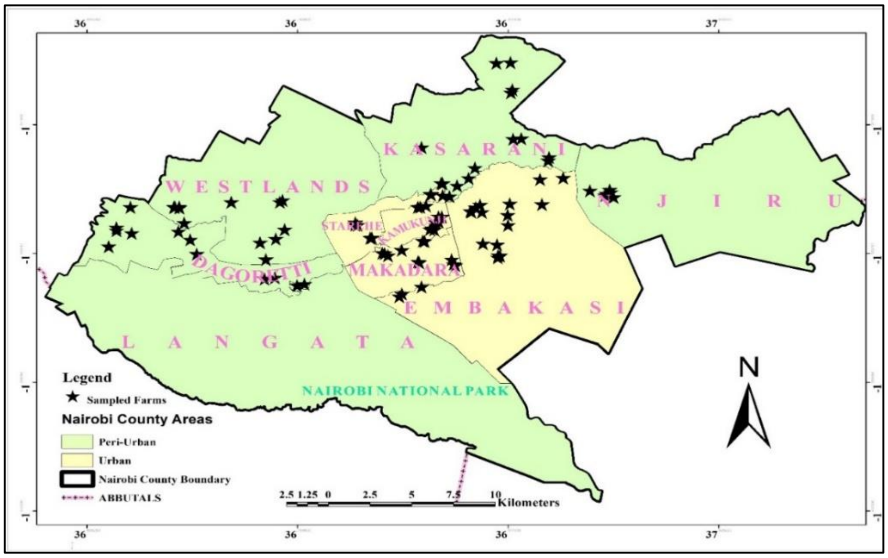

Figure 3. 2: Map showing location of sampled farms of UPUA farmers who were interviewed in Nairobi County. (Source: Ogendi et al., 2019)

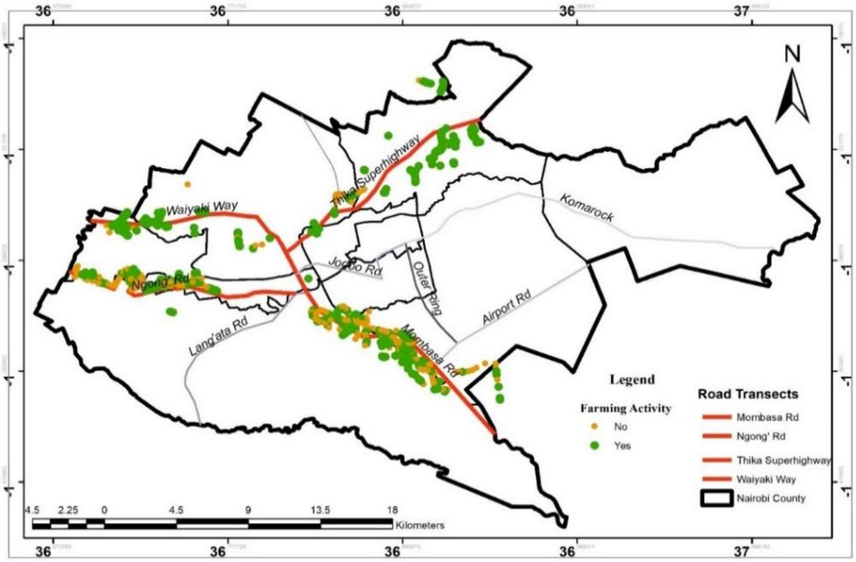

Figure 3. 3: Map showing presence of farming activities along four major road transect in Nairobi County, Kenya. (Source: Ogendi *et al*., 2021)

3.7 Data Analysis

Geographical coordinates collected by use of a GPS were loaded onto ArcGIS software as shapefiles and ArcMap version 10.3 was used to process maps of sampled sites and localities. The survey data collected was checked, cleaned, coded and input on a spreadsheet. Statistical analysis was performed. The data was subjected to descriptive analysis using the Statistical Package for the Social Sciences (SPSS Version 20). General inferences were presented using percentages and proportions. In determining any association between variables, contingency tables (Pearson chi-square) was used to obtain results. Further tests (Fishers t-tests) were done to determine whether the differences were statistically significant between urban and peri-urban areas. All data was analyzed at 5% level of significance. Results were presented using tables, pie charts, bar graphs, photographs and maps.

CHAPTER FOUR

RESULTS AND DISCUSSION

The results and discussion of distribution of urban and peri-urban agriculture production systems and occurrence level of farming activities along major network links are presented in this section. Sub section 4.1 presents results and discussion of distribution of production systems for UPUA. Sub section 4.2 presents results and discussion of occurrence level of farming activities across major networks links of Nairobi County.

4.1 Distribution of urban and peri-urban agriculture production systems in Nairobi County, Kenya

4.1.1: Socio-economic characteristics of UPUA respondents in Nairobi County

Most UPUA households constituted 4 to 6 members (38.9%) and combined figures indicated that 78.9% of households had more than 4 family members (Table 4.1a). Majority of the respondents were male (70.5%) and were in the age bracket of 18 and 35 years (34.7%; Table 4.1). It was clear that majority of respondents engaged in urban and peri-urban agriculture (UPUA) constituting 68.4% were of employable age (ranging from 18 to 50 years age). Those above 65 years old were a minority (8.4%). This implies that UPUA is practised as a form of employment. A majority of the UPUA farmers had attained formal education (primary and secondary education) constituting 65.3% and a notable proportion had attained post-secondary education (33.7%; Table 4.1). This is a good indicator that most of these farmers are trainable and can be involved in capacity building programmes like value addition to farm produce. The farmers were mainly engaged in both livestock rearing and growing crops (54.7%) although a good number of them were practicing crop cultivation only (45.3%). In terms of UPUA engagement, farmers who solely depended on it for sustainability constituted the largest category (37.9%), seconded by those who were both in business and farming (32.6%; Table 4.1).

More time was committed for crop production than livestock rearing in Nairobi City County (Table 4.1). Over 70% of livestock farming activities (the average for each UPUA farmer) were undertaken in less than 4 hours per day. It is only crop production that consumed more than 9 hours per day in the farming activities.

Table 4.1: Socio-economic characteristics (A) of UPUA respondents in Nairobi County (n=95)

Attribute	Level	Frequency	Percent
Gender	Men	67	70.5
	Women	28	29.5
Age	18 to 35 years	33	34.7
	36 to 50 years	32	33.7
	51 to 65 years	22	23.2
	Over 65 years	8	8.4
	None	1	1.1
Education	Primary	23	24.2
	Secondary	39	41.1
	Tertiary	32	33.7
Occupation	Govt –permanent	10	10.5
	Govt-contract	4	4.2
	Private-permanent	5	5.3
	Private-contract	6	6.3
	Casual	1	1.1
	Business	31	32.6
	Full time farming	36	37.9
	Voluntary work	2	2.1
UPUA income	Less than 25%	15	15.8
	25-50%	22	23.2
	51-75%	26	27.4
	More than 75%	32	33.7
Household size	1 to 3 members	20	21.1
	4 to 6 members	37	38.9
	7 to10 members	22	23.2
	More than10	16	16.8
Agricultural enterprise	Crops only	43	45.3
	Crops and livestock	52	54.7
	Livestock only	0	0.0
Time used (hours/day) for crop production	Less than 2 hours	8	8.4
	2 to 4 hours	32	33.7
	5-8 hours	29	30.5
	9 to 12 hours	26	27.4
Time used (hours/day) for livestock rearing	Less than 2 hours	9	17.3
	2 to 4 hours	38	73.1
	5-8 hours	5	9.6
	9 to 12 hours	0	0.0

Most of the UPUA farmers had undertaken their farming ventures for period not more than two years (Table 4.2). A smaller percentage (15.8%) of respondents had the longest period of experience of more than 15 years practicing UPUA farming. Most of the UPUA farmers utilized idle land (52.6%) for their farming activities in Nairobi City County (Table 4.2). Some of the other UPUA farmers acquired their land through renting (13.7%), purchasing (11.6%), making local arrangement with their respective local institutional administrators to use the land freely (10.5%), inheritance (7.4%) and caretaking (4.2%) of other's land/plot. There was significant difference in level of utilization of different water sources. The level of utilization of piped water for farming activities was significantly higher (41.1%, $P < 0.05$) than other water sources in Nairobi City County (Table 4.2). However, some of the respondents used domestic waste water (9.5%) and raw sewage (5.3%) by channelling into their farms for irrigation. The use of unclean (untreated sewage) water for irrigation is as a result of constant water shortage spells especially to the urban poor. This is doubled by lack of rains during dry seasons for those who depend solely on the rains for irrigation water. However, the use of the water is not as rampant as most of the famers are informed of the negative implications on their health. (Owuor *et al*., 2017) state that piped water is inaccessible and costly to the urban poor as compared to the high-income population who are able to access and afford the cost. This leaves the urban poor with few options and are always looking for ways to irrigate their crops. Comparatively, more land area was utilized for crop production than livestock rearing in Nairobi City County (Table 4.2). Over 90% of livestock farming (the average for each UPUA farmer) was undertaken in land/space which was less than a quarter of an acre.

The highest proportion of respondents (33.7%) generated more than 75% of their gross income from UPUA activities as source of livelihood. Combined figures indicated that more than 51% of gross income was generated from UPUA farming for 61.1 % of the total respondents (Table 4.3). Income contribution from agriculture for active farmers in Njiru was more than 75% and in Kasarani (Peri-urban areas) it was 51% to 75% of total income). Active farmers in Peri-urban areas substantially benefited from income generated from farming activities. More farmers in peri-urban areas undertook farming as a full-time occupation compared to farmers in urban areas. This could be explained by larger pieces of land available in peri-urban areas so that farmers in urban areas did farming mainly for subsistence. Casual labourers were least engaged in UPUA farming (1.1%) and this could be attributed to lack of income which could be injected into farming and lack of time to engage on their own UPUA ventures. In most of the occasions, casuals are employed on other peoples’ undertakings in terms of labour force utility.

Table 4 2: Socio-economic characteristics (B) of UPUA respondents in Nairobi County (n=95)

Attribute	Level	Frequency	Percent
Years of experience in UPUA	Less than 1 year	14	14.7
	1 to 2 years	25	26.3
	3 to 5 years	16	16.8
	6 to 10 years	19	20.0
	11 to 15 years	6	6.3
	More than 15 years	15	15.8
Land ownership for UPUA	Institutional land	51	54.3
	Personal/private land	30	31.6
	Nairobi city council land	1	0.6
	Unscheduled land	13	13.5
Size of land (acres) used for crop production	Less than ¼ acre	37	38.9
	¼ to ½ acre	17	17.9
	½ to 1 acre	19	20.0
	1 to 2 acres	11	11.6
	More than 2 acres	11	11.6
Size of land (acres) used for livestock rearing	Less than ¼ acre	49	90.7
	¼ to ½ acre	2	3.7
	½ to 1 acre	1	1.9
	1 to 2 acres	0	0.0
	More than 2 acres	2	3.7
Mode of acquisition of land for UPUA	Bought	11	11.6
	Inherited	7	7.4
	Rented	13	13.7
	Caretaking for someone	4	4.2
	Freely permitted by local authority No permission (idle	10	10.5
	space) /grabbing	50	52.6
Source of water for UPUA	Piped water	39	41.1
	Borehole water	19	20.0
	Spring water	12	12.1
	River water	6	6.3
	Rain water	3	3.2
	Swamp water	2	2.1
	Domestic waste water	9	9.5
	Raw sewage water	5	5.3
Number of UPUA farmers interviewed	Urban areas	55	57.9
	Peri-urban areas	40	42.1

Table 4.3: UPUA income contribution (%) to total income by sub county for respondents in Nairobi County (n=95)

		How much does income from UPUA contribute to your total income earnings (in percentage)?				
		Less than 25%	**25-50%**	**51-75%**	**More than 75%**	**Total (%)**
Sub County	Kasarani	6.3	6.3	62.5	25.0	100
	Starehe	9.1	36.4	36.4	18.2	100
	Makadara	0.0	25.0	25.0	50.0	100
	Kamukunji	38.5	15.4	15.4	30.8	100
	Embakasi	12.5	12.5	50.0	25.0	100
	Njiru	6.7	26.7	6.7	60.0	100
	Westlands	25.0	33.3	16.7	25.0	100
	Dagoretti	25.0	33.3	8.3	33.3	100

4.1.2: Crop production technologies in relation to some socio-economic characteristics

4.1.2.1: Crop production technologies and land size

There was significant difference in size of land / space utilized by different crop production technologies. Crop production technologies of open field, multi-storey, micro garden and moist-bed were significantly (P=0.014) more on land/space (29.2%) which was less than a quarter of an acre (Fig. 4.1). Open field technology was practiced on relatively large land size, greater than 1 acre, accounting for more than 12.4% and mainly in the peri-urban areas (Fig. 4.2). Multi-storey garden technology was preferred in urban areas and was practiced on small land size (less than a quarter acre of land). Other least used technologies were also practiced on small land size (less than a quarter acreage) in urban areas especially balcony garden, rooftop garden and hanging garden technologies. The study findings are in agreement with Githugunyi (2014) who reported that farmers adopted technologies which are land intensive in order to cope with inadequate land in highly populated areas of Roysambu ward in Nairobi County. Availability of land in and around cities presents the most limiting factor to crop production (Foeken and Owuor, 2008; Orsini *et al*., 2013; Simiyu, 2013). In their research work done at Bahir Dar in Ethiopia, Haregeweyn et al. (2012) suggested that there is a strong linkage between urban growth and agriculture, as urbanization leads to loss of agricultural land in and around cities. Aubry *et al.* (2013) reveal that lack of access to land is a major constraint for the farming urban poor households in cities forcing them to depend on rural food for their livelihood. Agricultural land on the peri-urban fringe of Nairobi City is constantly and rapidly diminishing due to competition from other land uses such as construction of residential and commercial buildings (Thuo, 2013) among other economic reasons. There is thus need to develop policies for protecting potentially usable land for urban agriculture through urban planning and improving technologies appropriate for built-up areas.

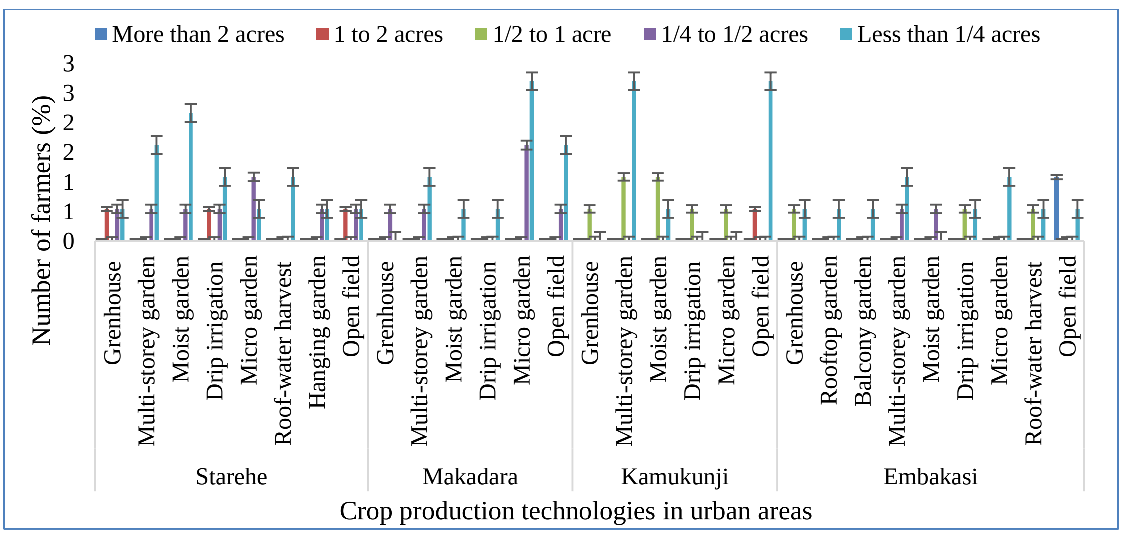

Figure 4. 1: Proportion of farmers utilizing various land/space sizes in relation to type of crop production technologies in urban areas of Nairobi County, Kenya

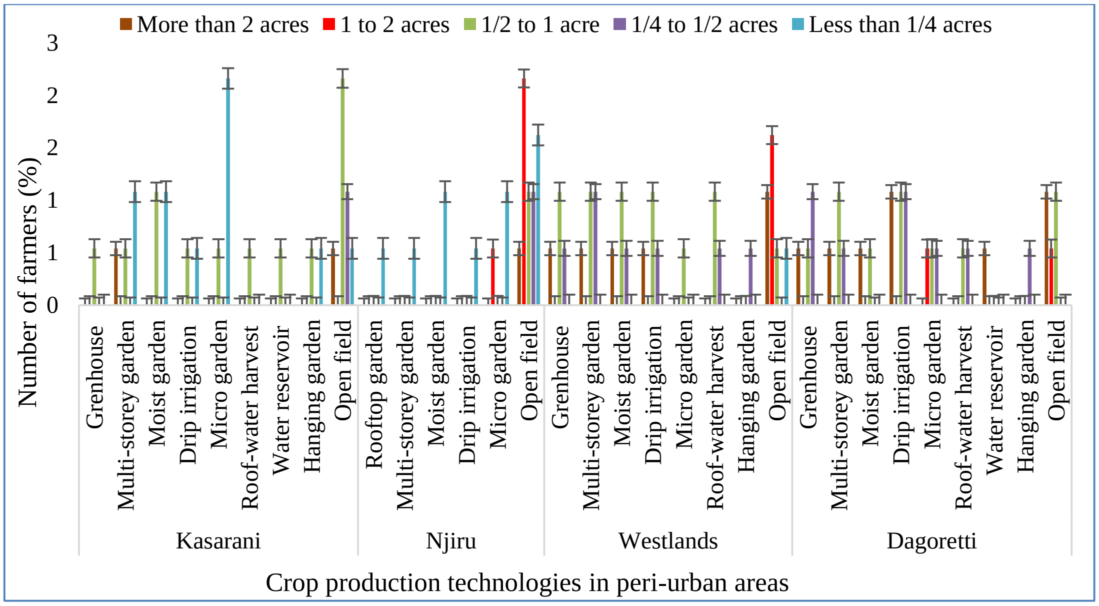

Figure 4. 2: Proportion of farmers utilizing various land/space sizes in relation to type of crop production technologies in peri-urban areas of Nairobi County, Kenya

4.1.2.2: Crop production technologies and land ownership

On land ownership, institutional land constituted the most significant (*P*=0.012) available land (54.2%) utilizing all except 3 technologies (water reservoir, rooftop garden and balcony garden (Fig.4.3; Fig.4.4). It was available both in urban (26.6%) and peri-urban (27.7%) areas and was mostly accessed through arrangement with respective local institutional administration (Fig 4.5). Personal land was also available but significantly higher (*P*=0.023) in peri-urban (22.6%) than in urban areas (5.6%). Unscheduled land/spaces were used almost in equal proportions both in urban areas (7.3%) and peri-urban areas (6.2%). Family land was mainly available in peri-urban area (3.4%). Land allocated by Nairobi City Council was the least available. From interview with officers from the District Physical Planning department, it was revealed that colonial land ownership in Nairobi City contributed to land scarcity; as only a few individuals and institutions owned vast tracks of land within the city. This concurred with our findings whereby although institutional and personal (private) owned lands were the most used by the city farmers much more land remained tied up by large institutions. For instance, one High School in Dagoretti Sub County (which is in a peri-urban area) had more than five acres of undeveloped land lying idle, in addition to another five acres which was under agricultural production (open field). Commenting on land use in Nairobi fringe (peri-urban), Thuo (2013) noted that dual legal systems (customary and formal) of land ownership constrain the control of land use. He further noted that sub-division of land for inheritance, a common habit in customary land use, had led to fragmentation of landholdings into uneconomical parcels for agricultural purpose. Land used for UPUA is dominated by informal arrangements (Robineau & Dogue, 2018) and farming households are involved in numerous informal land transactions (Simiyu, 2013). Follmann *et al.* (2021) argue that UPUA is being pushed into the peripheries in some cities due to "intensification and commercialization processes" that result in new or changing types of farming. Farmer responses depend on socio-economic status and existing land regimes (Follmann *et al.*, 2021) meaning a land-secure farmer can invest on the land whereas the land-insecure one is faced with many struggles.

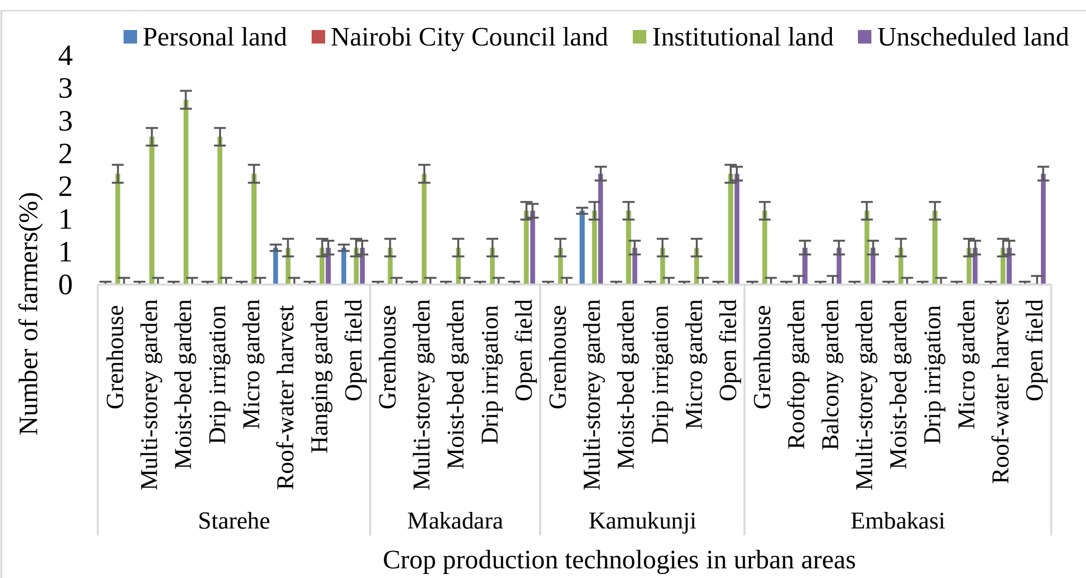

Figure 4. 3: Distribution of type of land/space ownership utilized for different crop production technologies in urban areas of Nairobi County, Kenya

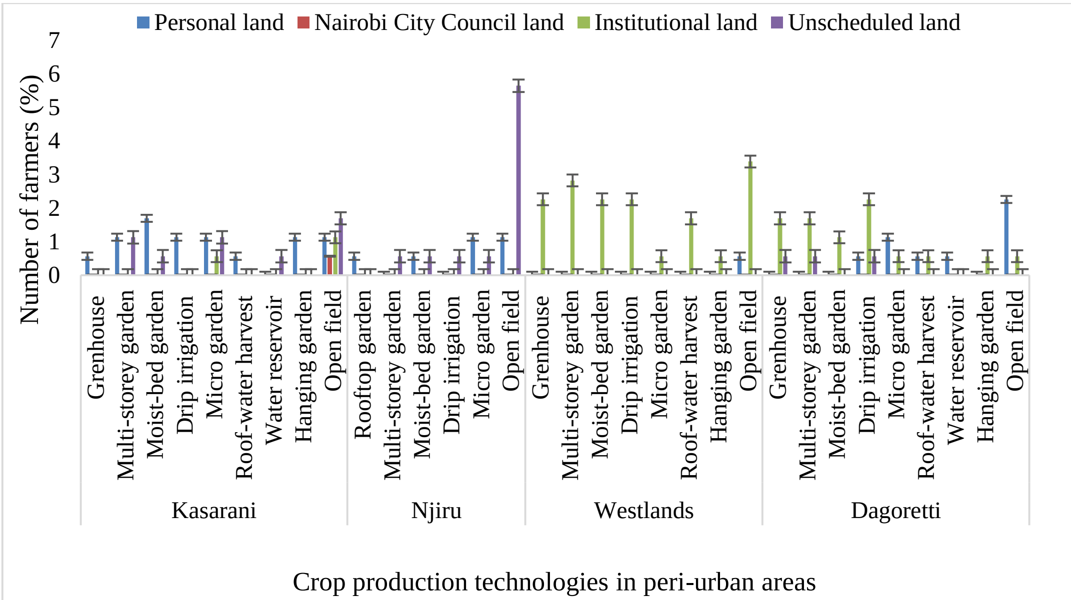

Figure 4. 4: Distribution of type of land/space ownership utilized for different crop production technologies in peri-urban areas of Nairobi County, Kenya

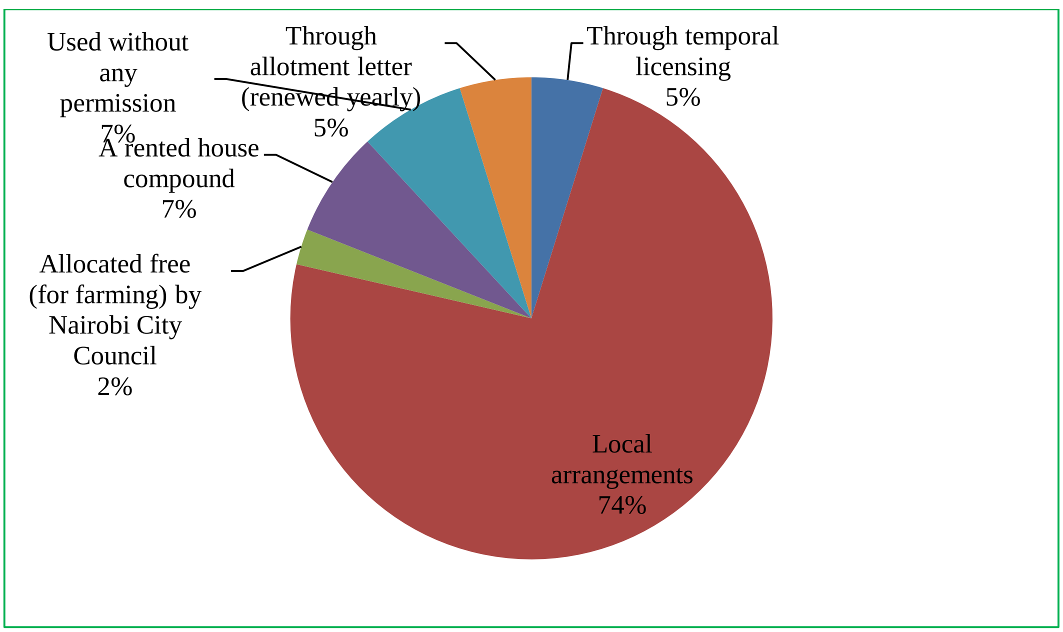

Figure 4. 5: Various means of accessing institutional land for urban and peri-urban agriculture in Nairobi County, Kenya

Among the unscheduled land/spaces, riparian land was more utilized for crop production in urban areas (25%), whereas in the peri-urban areas, road reserves (15%) and spaces under electrical power lines (15%) were most used for agriculture, though these were not significantly different ($P>0.05$) from the other types of unscheduled spaces (Fig 4.6). In their findings, Njenga *et al*. (2010) observed that agriculture in Nairobi City was practiced on open spaces under power lines, along river banks, roadsides and railway lines. Simiyu (2012) noted that the need for farming space by the urban poor in Eldoret town, Kenya, forced them to invade vacant public spaces such as underdeveloped lands belonging to Kenya Railways and Eldoret Municipal Council.

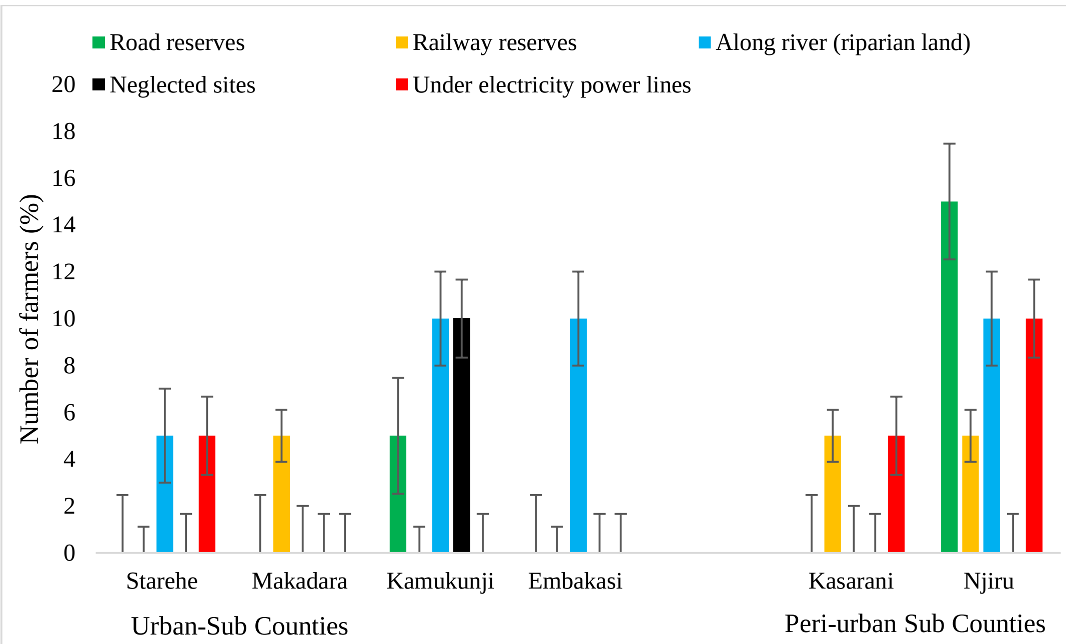

Figure 4. 6: Extent of utilization of different types of unscheduled spaces for crop production in urban and peri-urban areas of Nairobi County, Kenya

4.1.2.3: Crop production technologies and household head

Male-headed households significantly ($P=0.008$) utilized most crop production technologies for UPUA except hanging, rooftop and balcony garden technologies (Fig

4.7). Open field (24.9%), multi-storey garden (16.4%) and moist-bed garden (11.9%) were the most utilized technologies for crop production by male-headed households. Female-headed households mostly utilized open field (2.3%) and micro-garden (1.7%) technologies. The male dominance in the practice of these crop production technologies could be probably due to the demanding farming tasks involved such as land and manure/compost preparation (in case of open field technology) and the installation of multi-storey and / or moist-bed garden technologies such as transporting and filling sacks/polythene bags with potting soil. This observation was in agreement with Cofie *et al*. (2008) who noted that gender differences in farming could be due to the laboriousness of ‘farm work’. The gender cultural role could also be another reason as to why male-headed households had the upper hand on the utilization of the crop production technologies. A man is usually known to be the bread winner and since most of the interviewed respondents were active farmers, it is therefore logical that the males were actively involved for their household food provision. Crowded living areas and inaccessibility to farming land are some of the challenges that limit urban poor households especially those headed by female to access food and nutritional security through urban farming activities (Lee-Smith, 2010).

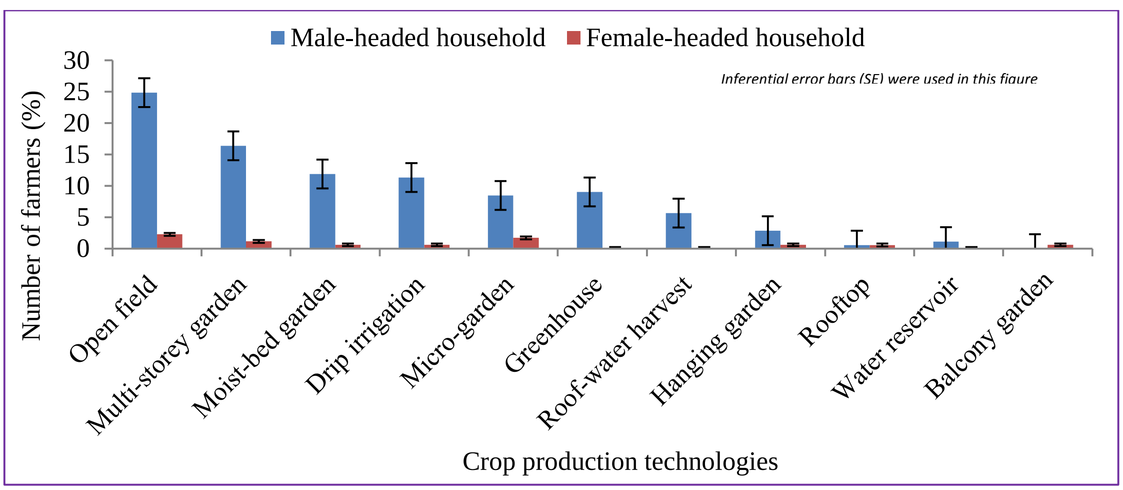

Figure 4. 7: Utilization of crop production technologies for UPUA by male and female headed households in Nairobi County, Kenya

4.1.3: Utilization of crop produce, challenges faced and attitude perception by UPUA respondents in Nairobi County

The produce from the cultivated indigenous vegetables (51.9%), exotic vegetables (52.1%), fruit trees (53.4%) and herbs and spices (54.4%) were notably used for home consumption (Fig 4.6). Owuor *et al*. (2017) state that production of fruits and vegetables predominates in some parts of Nairobi County, for the readily available local market. Respondents reported that they were able to sell surplus (<50%) of the produce from grown categories of vegetables as a means of income generation to use in meeting other household needs.

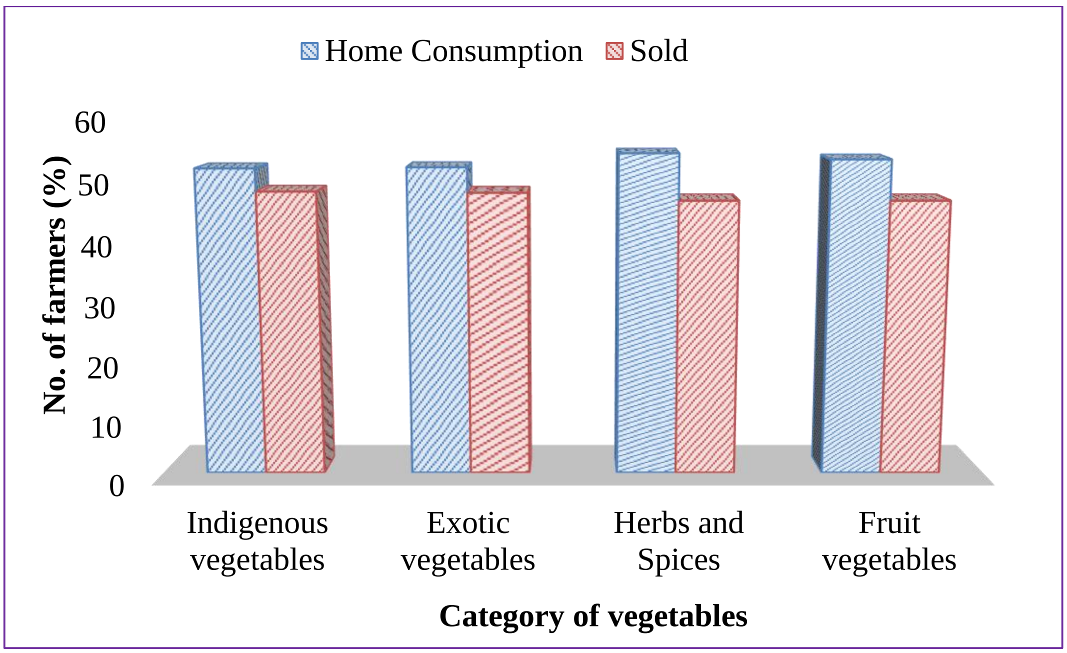

Figure 4. 8: Utilization of various categories of vegetable produce from UPUA in Nairobi County

The most daunting challenges facing UPUA farmers in order of importance included scarcity of water (37.9%), lack of access to capital (13.7%), limited land (11.6%), pest and diseases (11.6%), theft of farm produce (6.3%) and lack of cheap labour (6.3%) for farming (Table 4.4). There was no association between the challenges and sub counties (χ^2=168.754; DF=97; p=0.215). The farmers in the Nairobi County generally perceived urban planners' attitude towards farming activities as intimidating rather than supportive (Fig 4.9). Intimidation incidences were reported more frequently in Dagoretti Sub County. The respondents reported incidences of intimidation from the authority experienced when their crops were slashed down by the Nairobi City Council police officers. However, some farmers reported receiving support from urban planners especially in Makadara Sub County. There was no association between sub counties and the perceived urban planners' attitude towards UPUA (χ^2=6.830; DF=7; p=0.447).

Table 4. 4: Type and degree of prevalence of challenges faced by urban and peri-urban farmers in Nairobi County, Kenya

	Urban sub Counties					**Peri-urban Sub Counties**					
Challenges*:*	**Sta**	**Mak**	**Kam**	**Emb**	**Subt (%)**	**Kas**	**Nji**	**Wes**	**Dag**	**Subt (%)**	**Total (%)**
Scarce water	6.3	4.2	7.4	2.1	20.0	5.3	4.2	5.3	3.2	17.9	57.9
Lack of access to capital	0.0	0.0	0.0	3.2	3.2	1.1	2.1	1.1	6.3	10.5	16.8
Limited land	0.0	0.0	3.2	1.1	4.2	2.1	2.1	1.1	2.1	7.4	15.8
Pests and diseases	2.1	1.1	1.1	0.0	4.2	1.1	3.2	3.2	0.0	7.4	15.8
Theft	1.1	0.0	1.1	0.0	2.1	3.2	1.1	0.0	0.0	4.2	8.4
Lack of labour	0.0	1.1	0.0	0.0	1.1	2.1	1.1	1.1	1.1	5.3	7.4
Roaming livestock	0.0	1.1	1.1	1.1	3.2	0.0	0.0	0.0	0.0	0.0	6.3
Flooding during rains	1.1	0.0	0.0	0.0	1.1	1.1	0.0	0.0	0.0	1.1	3.2
Lack of space for toilets	1.1	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	2.1
conflict of land ownership	0.0	1.1	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	2.1
Lack of technical support	0.0	0.0	0.0	1.1	1.1	0.0	0.0	0.0	0.0	0.0	2.1
Marketing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.1	1.1
High land renting charges	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	1.1	1.1
Lack of inputs	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	1.1	1.1
No challenge	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	1.1	1.1
Pearson chi square =168.754; df=97; p=0.215											

Key: Sta-Starehe; mak-Makadara; kam-Kamukunji; emb-Embakasi; subt-sub-total; Kas-kasarani; Nji-njiru; wes-Westlands; dag-Dagoretti.

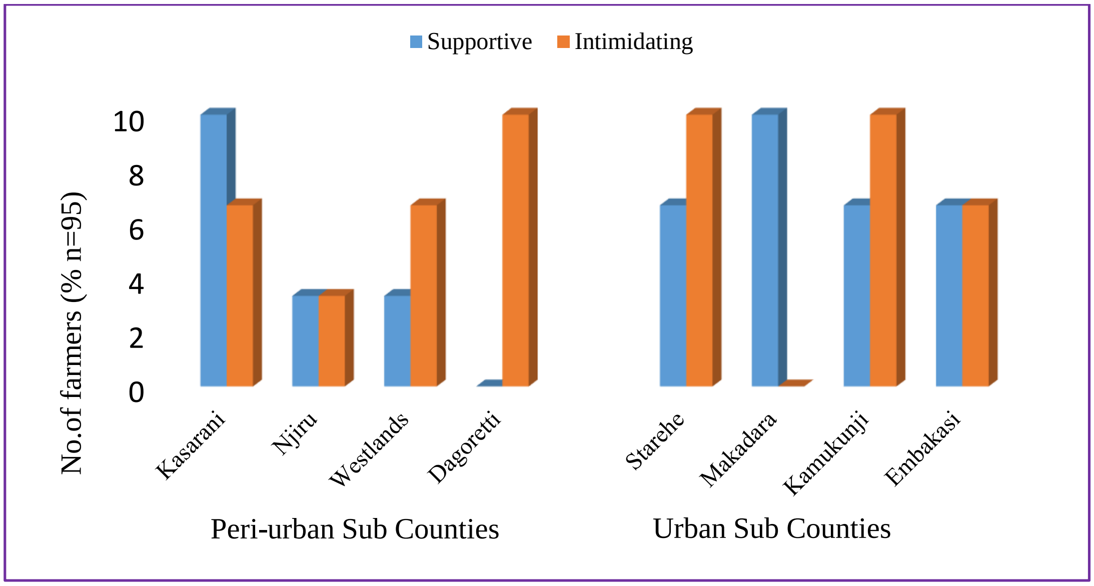

Figure 4. 9: The perceived attitude (by farmers) about urban planners in Nairobi City County towards farming activities in the urban and peri-urban areas

4.1.4: Distribution of crop production technologies for UPUA in Nairobi County

Table 4. 5: Preference (%) of crop production technologies in 8 sub counties of Nairobi County (n=95)

	Urban sub counties					Peri-urban sub counties					Ovtl
Production Technologies	**Sta**	**Kam**	**Emb**	**Mak**	**Tot**	**Wes**	**Dag**	**Kas**	**Nji**	**Tot**	
Open field	1.7	2.8	1.7	2.3	8.5	4.0	2.8	4.5	6.8	18.1	26.6
Multi-storey garden	2.3	4	1.7	1.7	9.7	2.8	2.3	2.3	0.6	8.0	17.7
Moist-bed gardening	2.8	1.7	0.6	0.6	5.7	2.3	1.1	2.3	1.1	6.8	12.5
Drip irrigation kit	2.3	0.6	1.1	0.6	4.6	2.3	3.4	1.1	0.6	7.4	12.0
Micro garden	1.7	0.6	1.1	0	3.4	0.6	1.7	2.8	1.7	6.8	10.2
Greenhouse	1.7	0.6	1.1	0.6	4	2.3	2.3	0.6	0	5.2	9.2
Roof water harvesting	1.1	0	1.1	0	2.2	1.7	1.1	0.6	0	3.4	5.6
Hanging garden	1.1	0	0	0	1.1	0.6	0.6	1.1	0	2.3	3.4
Rooftop garden	0	0	0.6	0	0.6	0	0	0	0.6	0.6	1.2
Water reservoir	0	0	0	0	0	0	0.6	0.6	0	1.2	1.2
Balcony garden	0	0	0.6	0	0.6	0	0	0	0	0	0.6
Total percentage	14.7	10.3	9.6	5.8		16.6	15.9	15.9	11		100
					40.4					59.6	

Key: Sta-Starehe; mak-Makadara; kam-Kamukunji; emb-Embakasi; subt-sub-total; Kas-kasarani; Nji-njiru; wes-Westlands; dag-Dagoretti.

Eleven technologies were identified being utilized among urban and peri-urban farmers in Nairobi County (Table 4.5). Open field technology (Plate 4.1) was the most utilized crop production technology (26.6%) and was significantly (*P*=0.033) more in use at the peri-urban than urban areas. It was mostly utilized by farmers in Njiru Sub County (6.8%). In open field technology, farming activities are done directly on land and usually on the existing soil. In this study, cereal crops (maize, sorghum), legumes (common beans, cowpeas, garden peas, and soybeans), industrial crops (sugar cane), fodder crops (*Lucerne*, *Napier* grass), vegetables (kales, onions, carrots, cabbage, etc.) were mostly grown using this type of technology. The field is tilled and prepared for planting, manure (compost or farm yard) is mixed then planting or transplanting of crop of choice is done. Farm management practices like irrigation, weeding etc. are done to maturity and harvesting of the crop. This type of technology can be labour intensive depending on the size of the land available for farming activities. This technology is usually limited to places where vacant land/space is available, thus was not common in the built-up/paved areas (especially in urban areas). It is expected that as rapid urbanization continues taking over spaces in cities and towns, this production method will decline or be replaced.

Plate 4. 1: Open field crop production spaces at Ruai Estate in Njiru sub county, Nairobi County, Kenya. (Source: Author, 2014)

Multi-storey garden was the second popular technology (Table 4.5; Plate 4.2) and more in use in the urban (9.7%) than in the peri-urban areas (8%) and especially in Kamukunji Sub County (4%). This could be attributed to lack of adequate land/space for farming in the urban areas. Derivative names for this technology are sack garden and vertical garden. Sacks (either sisal or polythene) and gunny bags are used to construct this type of crop production system. Planting media is prepared by mixing soil and well composited manure and/ or fertilizer. Then the bag/sack is placed in the preferred location using poles on four corners to make it stand. A hollow pipe is then placed in the middle of the bag/sack. The gunny bag is then slowly filled with the planting media around it, at the same time adding gravel into the hollow pipe at the centre which allows for aeration and distribution of water throughout the bag. Keep on lifting the hollow pipe up as media is filled round it until the top. To maximize on space and yield, planting holes are made round the sack/bag by piercing through it. Plant seedlings are then inserted on top sides and even around it if possible. A research conducted at Kibera slums by Karanja *et al* (2010) noted that a 90kg sack can carry 45-50 plants of Kales and give a yield of 30kgs every 2 months. This garden can be re-constructed after a period of 3 years. Polythene bags last longer compared to other type of sack. New bags will also last longer compared to recycled bags/sacks. The system is not portable, therefore when relocating, it is destroyed in order to salvage the bag/sack for the next location. The technology is space and water efficient.

Farming households in highly-space constrained environment of Nairobi County preferred use of multi-storey gardening technology for vegetable production as it can support growth of many plants in a very small space, by utilizing the vertical space. This concurs with observations of Gallaher *et al*. (2015) who stated that multi-storey gardening is a sustainable livelihood strategy for poor farming households in the urban environment. The method is becoming famous and is embraced by all urban dwellers of all economic classes. It fits best where land is scarce in built-up areas or congested places/ homesteads.

Plate 4. 2: Vegetable crops grown using multi-storey production technology at Bahati Estate in Kamukunji sub county, Nairobi County, Kenya. (Source: Author, 2014)

Moist-bed garden (Table 4.5; Plate 4.3) was the third most utilized technology (12.5%) and mostly in urban areas especially Starehe sub county (2.8%). This technology comes handy in saving irrigation water and also growing plants that love wet conditions such as rice and arrow root crops. It is also called wet-bed garden. Impermeable polythene sheets are laid on the ground and filled with soil/planting media and thoroughly watered before planting. The amounts of water and soil type to use depend on type of crop to be grown. For arrow roots and rice, clayey soil which holds water for longer is used. For other crops like strawberries and vegetables, well-draining soils are used. There are several versions of this technology practiced by the farmers. Some farmers construct it by first digging a hole/trench, then line it with an impermeable polythene sheet before filling with planting media. Others put support around using stones/blocks (to raise the ends of polythene sheet like a receptacle) then line with polythene sheet before filling it with planting media. Drip irrigation technique (Plate 4.4) was the fourth most utilized technology (12%) and was found in peri-urban areas especially Dagoretti and Westland Sub Counties.

Plate 4. 3: Arrow roots, strawberry and kales grown using moist-bed garden at Ziwani Estate in Starehe sub county, Nairobi County, Kenya. (Source: Author, 2014)

Drip irrigation technique (Plate 4.4) was the fourth most utilized technology (12%) and was found in peri-urban areas especially Dagoretti and Westland Sub County. This is a type of irrigation that emerged to aid in saving water due to water scarcity and cost. It is a micro-irrigation system that allows water to trickle to plant roots slowly from above or below the soil surface. The system distributes water to crop roots through valves, pipes, tubing and emitters. The many advantages of this system include the minimal and efficient use of water and fertilizer, reduced soil erosion, weed growth, disease risks and labour costs.

Disadvantages of the system include the high initial cost of purchasing and installing it, and technical expertise needed for properly installation and maintenance. Drip irrigation technology is incorporated with both greenhouse and open-field technologies. It is limited to only high-value crops to guarantee returns due to high capital costs of installation and maintenance.

Plate 4. 4: *Capsicum* and tomatoes grown using drip irrigation crop production technology Highridge Estate in Westlands Sub County in Nairobi County, Kenya.(Source: Author, 2014)

Micro garden (Plate 4.5) was the 5th most utilized technology (10.2%) and was found mostly in peri-urban areas especially Kasarani sub county (Table 4.5). These are small production units in containers for vegetables, roots, tubers and herbs in small spaces within an urban setup where limited space and scarcity of water prevails (FAO, 2014). Micro-gardens can be established almost everywhere and they allow urban land-less households to produce a broad range of vegetables for family consumption and sale to the neighbourhood (FAO, 2001).The urban farmers literally convert any container idling around for this miniature garden. Worn out shoes, hats, tires, basins crates, buckets, small bags/sacks, cement bags, plastic and metal tins, water-holding pots/drums, cooking pots, flasks, are some of the receptacles that were found used by farmers for this type of technology. The able farmers buy polythene sleeves, small sacks, flower pots or troughs for use. Receptacles made from cut bamboo sticks can also be used. A standard unit is a one (1) m^2 custom-built in table with a liner (FAO, 2014). One meter square ($1m^2$) in a micro garden can yield 30kg of tomatoes a year, 36 heads of lettuce every 60 days, ten (10) cabbages every three (3) months and 100 bulb onions every four (4) months. It is a simple and low-cost technology which can be embraced by both young and old farmers, needs little space yet it yields more and it purifies air and aids in household waste management by recycling to make compost as fertilizer (FAO, 2014).

Plate 4. 5: Vegetables are grown using micro-garden at Komarock Estate in Embakasi sub county, Nairobi County, Kenya. (Source: Author, 2014)

Greenhouse (Plate 4.6) was the sixth most prevalent technology (9.2%) and was found mostly in peri-urban areas especially in Westlands and Dagoretti Sub Counties. These are enclosed polythene sheet/ glass covered structures for crop production aimed for on and off-season higher yields as opposed to open field production. Due to limited land/space in urban areas, mini greenhouses are embraced for production of high value vegetables like tomatoes, chilies, capsicums, cucumbers and squash.

Roof water harvesting (Plate 4.7) was the 7th most utilized technology (5.6%) and was mainly found in Embakasi, Starehe and Westlands Sub Counties. The main feature of the system is collecting rain water from roofs during rainy season and storing it in tanks to irrigate crops. In many cities, water resources are becoming scarce and tap water is expensive. Rain water is free and can be collected to counter water shortages. Ridges are placed round the roof and connected to tanks below for water to collect into them. In a research conducted by FAO (2014), a roof of 20 m^2 can collect 2000 litres of water from each 100 mm rainfall, enough to support two (2) micro gardens of 1 m^2 each. By embracing this technology, crops for food can be grown throughout the year and help in alleviating hunger spells/food shortages in cities and towns.

Plate 4. 6: Tomatoes are grown using greenhouse crop production technology at Riruta Estate in Dagoretti Sub County, Nairobi County, Kenya. (Source: Author, 2014)

Plate 4. 7: Roof-water harvesting technology at Umoja Estate in Embakasi Sub County, Nairobi County, Kenya. (Source: author, 2014)

Hanging garden (Plate 4.8) was the eighth most utilized technology (3.4%) and noticeably used in peri-urban areas. It was especially found in Kasarani and Starehe Sub Counties (Table 4.5). These are containers planted with vegetables, herbs, small fruit crops and ornamental plants attached to or built on a wall. They are micro-urban farms suitable for farmers who are mobile or are temporarily living in a place. One can use this technology to grow fresh and safe vegetable crops for home consumption and sale the surplus. They exist in various sizes, shapes and modifications depending on what is locally available and the farmer’s creativity. From simple recyclable tins, buckets, crates, basins or jugs singly dangling on walls, to wooden structures crossing to support several containers with crops grown in them. They are also referred to as green edible walls.

Plate 4. 8: Kales and strawberry grown using hanging garden technology at Huruma estate in Starehe sub county, Nairobi County, Kenya. (Source: author, 2014)

Plate 4. 9: Kales, radish, capsicum, amaranth and spider plants grown on rooftop garden at Kayole estate in Embakasi sub county, Nairobi County, Kenya. (Source: author, 2014)

Rooftop garden (Plate 4.9) was among the least utilized crop technologies (1.2%) and only found in Embakasi and Njiru Sub Counties. Just as the name, the system is placed on roof tops of structures where there is no enough land for farming, especially highly populated and or highly built-up urban areas. Containers and raised beds are an easy approach to rooftop gardens but containers are perfect because they are flexible, affordable, portable and light.

Plate 4. 10: Kales, maize, sugarcane and bananas grown using water reservoir technology at Matopeni Estate in Njiru Sub County, Nairobi County, Kenya. (Source: author, 2014)

Water reservoir (Plate 4.10) was also among the least utilized crop technologies (1.2%) and only found in peri-urban Sub Counties of Dagoretti and Kasarani. This technology addresses the water shortage for UPUA. The ground is dug, polythene lining placed and water mostly rain water runoff is stored here for future irrigation or livestock use during dry spells. Balcony garden (Plate 4.11) was the least utilized crop production technology and was only found in Embakasi Sub County (0.6%). This is a technology specifically meant for those who love gardening but lack yard space in urban areas. Hanging pots and baskets are used as they hold many plants on the usually neglected overhead spaces. The technology does not require additional space since planters are attached either to the balcony wall or to the balcony railing. Depending on what one wants, vegetables, fruits or ornamental plants usually do well in this technology.

Plate 4. 11: Kales, spinach and amaranth grown on balcony space at Kayole Estate in Embakasi Sub County in Nairobi County, Kenya. (Source: author, 2014)

Rooftop and balcony gardens are widely used farming technologies in developed countries like North America and Europe (Thomaier *et al*., 2015), but are only slowly becoming common in the developing world (Hien *et al*., 2007); thus few UPUA farmers in Nairobi County are practicing them. Characterized by non-use of land or acreage (also termed as zero acreage farming) (Specht *et al*., 2014; Thomaier *et al*., 2015), rooftop and balcony garden technologies can be widely adopted in the urban areas to contribute towards sustainable urban agriculture. In their intensive study on rooftop gardens, Orsini *et al*. (2014) concluded that this technology can provide a crucial contribution to food accessibility in cities and be a tool for socialization and community building.

Most of the crop production technologies were practiced in sanitary neighbourhood which was mainly bad (47.3% [*32.7+14.6*]). It encompassed the presence of a dumping site, raw sewage channelled into farms, rivers / streams with polluted water and high human population density (Table 4.6; Plate 4.12; Plate 4.13). Here the farmers had selected and put up their chosen technologies such as Multi-storey garden in the midst and /or periphery of dumpsite and channelled waste water and raw untreated sewage directly into the crops. This provided moisture and nutrients to the crops.

Farming in the urban areas was done in worse sanitary neighbourhood conditions than in the peri-urban areas for almost all the identified crop production technologies (Table 4.5). It is only in the peri-urban areas that some of good sanitary neighbourhood conditions (17.6%) existed for various crop production technologies. The food safety of crops produced in urban environment is often questioned due to its proximity to a range of city pressures including road traffic, aircraft corridors, fuel filling stations and industrial areas (Leitão *et al*., 2016).

Farmers in the peri-urban areas practiced clean agriculture by irrigating with relatively clean water from Nairobi City Water and Sewerage Company. They also used water from unpolluted rivers/streams such as river Nyongara in Dagoretti Sub County, river Ruaka in Kasarani Sub County and/ or rain water harvested from roofs during wet seasons. This could partly be due to the fact that some farmers were aware of health implications with poor farming practices (Njenga *et al*., 2010). Proper urban planning and legislation on waste management could also have an impact on the environment for UPUA in Nairobi County (Njenga *et al*., 2010; Lee-Smith, 2013). It was evident that some farmers in Nairobi County were practicing agriculture in poor environment and using poor inputs probably due to food insecurity and impacts of rapid urbanization which comes with challenges of offering city dwellers with basic necessities like water and sanitation services. For instance, a mixed crop farmer utilizing open field technology at Kariobangi North Estate (Kasarani Sub County) irrigated his farm with polluted water from Mathare stream which was contaminated with residential effluents from neighbouring Mathare valley slums. In their findings, (Cofie *et al*., 2008) reported that farmers irrigate with water of poor quality such as waste water even from sewage pipes due to lack of a better choice. This is triggered more by the urban poor's high demand for vegetables. The increased demand has led farmers to literally use any open space around which includes reclaiming dumpsites (Cofie *et al*., 2008). Orsini *et al*. (2013) reported that using poor practices can have negative impact on human health and environment.

Table 4. 6: Crop production technologies in relation to neighbourhood sanitary status in urban and peri-urban areas of Nairobi City County, Kenya (n=95)

	Urban			Peri-urban			
Technology\Neighborhood	**Bad**	**Moderate**	**Good**	**Bad**	**Moderate**	**Good**	**Total**
Open field	7.4	1.7	0.0	3.4	11.3	3.4	27.2
Multi-storey garden	7.4	2.3	0.0	2.8	2.8	2.3	17.6
Moist-bed garden	3.9	1.7	0.0	1.7	2.8	2.3	12.4
Drip irrigation	4.0	0.6	0.0	2.2	2.3	2.8	11.9
Micro-garden	2.8	0.6	0.0	0.6	2.8	3.4	10.2
Greenhouse	3.4	0.6	0.0	2.2	1.1	1.7	9.0
Roof-water harvest	1.7	0.6	0.0	1.1	1.7	0.6	5.7
Hanging gardens	1.2	0.0	0.0	0.6	1.7	0.0	3.5
Rooftop garden	0.6	0.0	0.0	0.0	0.0	0.6	1.2
Water reservoir	0.0	0.0	0.0	0.0	0.6	0.6	1.2
Balcony garden	0.6	0.0	0.0	0.0	0.0	0.0	0.6
Total	32.7	8.1	0.0	14.6	27.1	17.6	100.0

Plate 4. 12: Open field technology in neighbourhood with dumpsite and raw sewage channelled into farm in Makadara and Kamukunji Sub Counties of Nairobi County, Kenya. (Source: author, 2014)

Plate 4. 13: Multi-storey and rooftop garden crop production technologies in neighbourhood with high population density at Kiambio Estate in Kamukunji and Dandora Estate in Njiru Sub Counties of Nairobi County, Kenya.

A few crop production technologies (Table 4.5; Plate 4.14) were practised in good sanitary neighbourhood (17.6%) and some were in neighbourhood with moderate sanitary conditions (35%). In that set up, a gently sloping topography and resulting drainage was good, the soils were fertile and not littered with pollutants (waste) and clean water was used for irrigating the crops. Some level of pest and disease management was practiced which led to clean, healthy and bountiful crops.

Plate 4. 14: Open field and greenhouse crop production technologies with good sanitary neighbourhood at Dam Village Estate in Westlands Sub County in Nairobi County, Kenya. (Source: author, 2014)

4.2 Occurrence level of farming activities across major network links of Nairobi County

4.2.1: Intensity of farming activities across the transects

Out of the 672 data points visited, 394 points (58.63%) had farming activities going on whereas 278 points (41.6%) did not have. There was an association between type of farming enterprise and the road transects (χ^2=74.054; DF=3; *p*=0.000). The farming enterprises involved in growing crops only were 90.61%, rearing livestock only 0.25% while those both growing crops and rearing livestock were 9.14% (Table 4.7). Mombasa road transect had the most farming activities at 33% whereas Waiyaki Way road transect had the least at 16% (Fig. 4.10). This was so possibly because some communities are gated and thus were inaccessible for the study. The intensity of farming activities generally increased with an increase of distance from access links/centers near the Nairobi City CBD to the further placed (outskirts) access links/centers along three major network links of Nairobi County (Fig 4.11). The number of farmers (farms) increased with increase in distance away from CBD. Built-up areas are found close to CBD and less buildings and more open spaces/ land are found as one moves to the peripheries of the city, encouraging activities such as farming. The exception was along Mombasa road transect whereby the reverse of that observation was true. The exceptional pattern of farming activities along Mombasa road transect could possibly be due to large land space at JKIA that is under airport regulations on human traffic and security control. It could also be that way due to the nature of communities living here (with a bit higher level of income). These findings were similar with those of Githugunyi (2014) who observed that agricultural land use pattern in Nairobi metropolitan area would show zones of gradually increasing intensity from the built-up edges to where the city has no direct influence upon agricultural practice.

Table 4. 7: Urban and peri-urban agriculture enterprises undertaken along four major road transects in Nairobi County, Kenya (n=394).

	Type of enterprises					
Transect	**Crops only**		**Livestock only**		**Both crops & livestock**	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Mombasa road	130	32.99	0	0.00	2	0.51
Ngong road	103	26.14	0	0.00	0	0.00
Thika Superhighway	83	21.07	0	0.00	15	3.81
Waiyaki way	41	10.41	1	0.25	19	4.82
Total	357	90.61	1	0.25	36	9.14

χ^2=74.054; DF=3; p=0.000

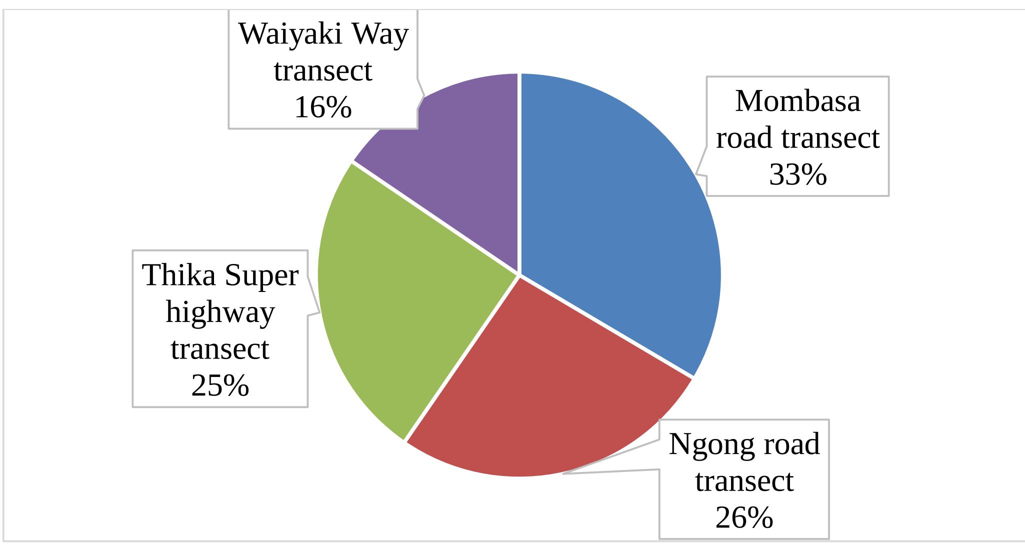

Figure 4. 10: Occurrence level of farming activities along four major network links in Nairobi County, Kenya

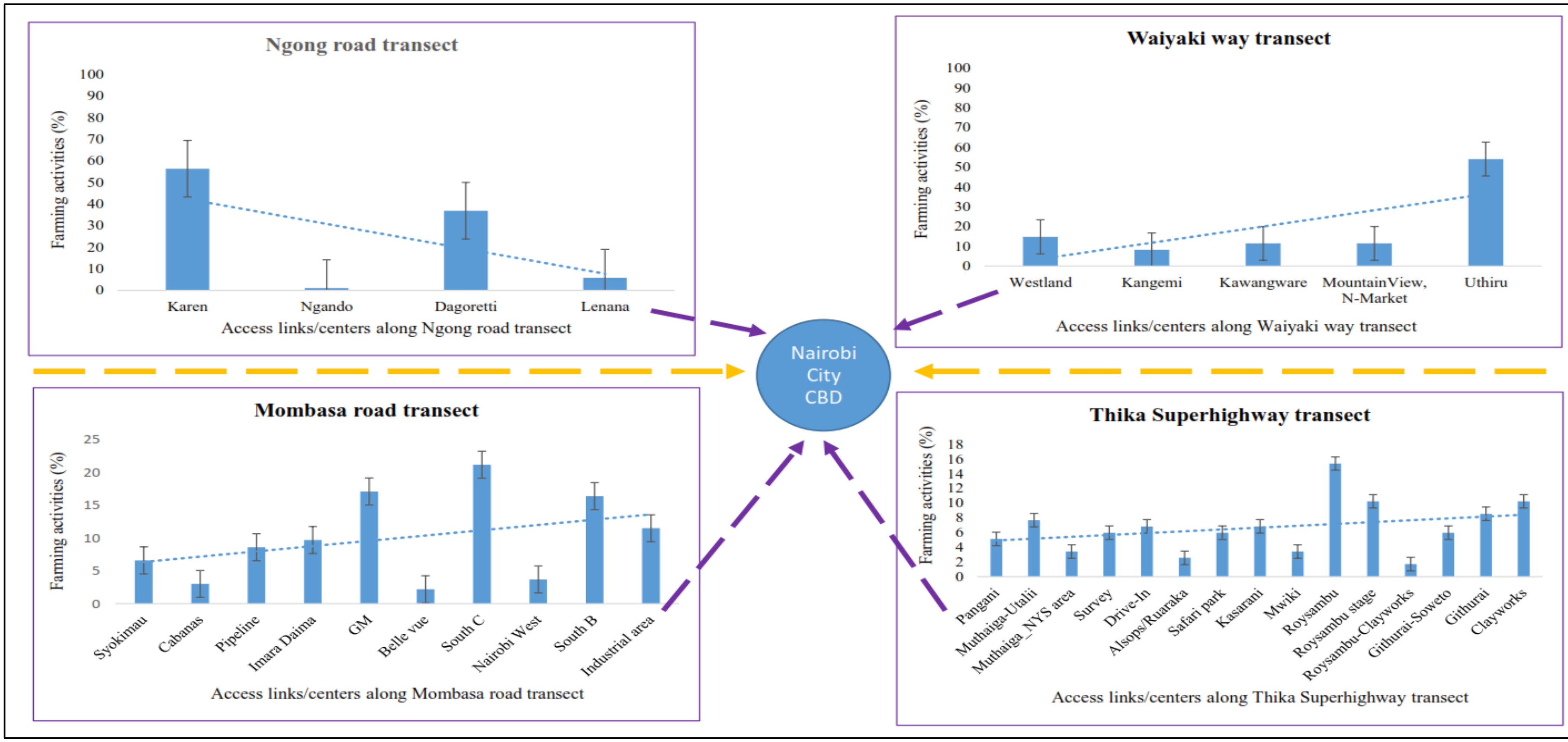

Figure 4. 11: Intensity of farming activities at access links/centres along four major road transects in Nairobi City County, Kenya

Fruits (27%) and vegetables (19.9%) were the major crops cultivated along the major network links while fodder (4.8%) and oil seed crops (0.3%) were the least grown crops (Table 4.8; Fig 4.10). There was an association between crops grown and the road transects (Table 4.9).

Table 4. 8: Breakdown of crop groupings observed in the field during survey in urban and peri-urban areas of Nairobi County, Kenya.

S/no.	Crop category	Names of crops in each category identified during survey
1.0	Fresh fruit and vegetables	
1.1	Fruits	Bananas, Guava, Citrus, Pawpaw, Avocado, Mango, Mulberries, Loquat, Passion fruit, Oranges
1.2	Vegetables	Cabbage, Spinach, Kales, Lettuce, Cauliflower, Broccoli, French bean, Cowpeas, African nightshade, Jute mallow, Amaranths, Spider plant, Slender leaf, Pumpkin, Tomatoes, Courgette, Cucumber, Radish, Onion, Coriander, Leek, Parsley, Fennel, Celery, Carrots, Lemon grass, Rosemary, Ginger
2.0	Staples	
2.1	Grains	Maize, Sorghum, Wheat
2.2	Pulses	Beans, Garden peas, Pigeon peas
2.3	Roots and tubers	Irish potatoes, Sweet potatoes, Cassava, Arrow roots, Yams
3.0	Other crops	
3.1	Oilseed crops	Soya beans, Ground nuts
3.2	Sugar crops	Sugarcane
3.4	Fodder crops	Napier grass, Lucerne
3.5	Ornamental plants	*Callistemon*, *Hibiscus*, *Cupressus*, *Durantas*, *Jacaranda*, *Euphorbia*, Kei apple, Roses, *Oleande*r, *Acalypha*, Ivy, Ferns, *Monstera*, Pine, Grevillea, *Eucalyptus*, *Dracaena*, *Bougainvillea*, *Spathodea*, *Schefflera*, *Brunfelsia*, *Aglaonema*

Table 4. 9: Pearson chi-square test results for crop categories grown across major network links of Nairobi County

Crop category	Chi-square value	*p*-value
Vegetables	63.888	0.013
Herbs and spices	38.368	0.000
Roots and tubers	60.918	0.000
Cereal crops	38.171	0.000
Fruit trees	30.371	0.000
Industrial crops	19.379	0.000
Fodder crops	61.289	0.000
Ornamental plants	27.230	0.000
Statistical test was done at 5% level of significance		

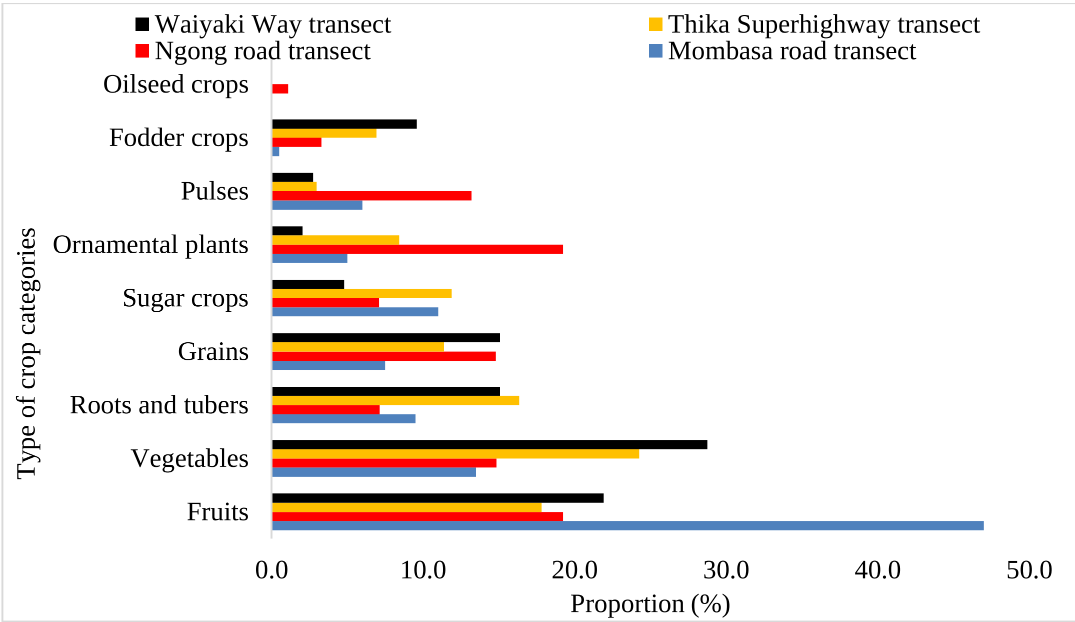

Figure 4. 12: Occurrence of various types of crops along four major road transects in Nairobi County, Kenya

Fruit crops (47%) were mostly found cultivated along Mombasa road transect (Fig 4.12). Fodder crops (9.6% and 6.9%) were mostly cultivated along Waiyaki Way and Thika Superhighway transects respectively. Roots and tubers (16.3%), vegetables (24.3%) and sugar crops (11.9%) were found mainly along Thika Superhighway. Grains (14.8%), pulses (13.2%), ornamental plants (19.2%) and oil seed (1.1%) crops were cultivated along Ngong road transect.

Poultry (38.5%) and cattle (34.6%) were the major livestock found along the 4 major networks in Nairobi County (Fig 4.13). Rabbits (5%) were only found reared along Thika Superhighway transect. Waiyaki Way transect had most of the livestock with highest proportion being cattle (37.9%) and poultry (37.9%), and lowest being fisheries (3.4%; Fig 4.13). There was an association between some of livestock reared and the road transects (Table 4.10).

Studies conducted by Alarcon *et al.* (2017) indicate that indeed Nairobi City County farmers do keep various categories of livestock; with dairy cattle keeping ranging from small scale to large scale. Alarcon *et al.* (2017) further revealed that most dairy cattle animals kept by Maasai beef fatteners were grazed along roads and river sides. Zero-grazed animals were fed with grass/hay cut along roads, yet still some beef keepers had small gardens with grass for their animals. Owuor *et al*. (2017) observed poultry, goats and sheep being reared within Nairobi City County. In another study, it was reported that commercial layers and indigenous chicken were kept in Dagoretti (Onono *et al*., 2018).These poultry play a significant role in supporting livelihood of urban and peri-urban households by providing eggs, income and chicken manure (Onono *et al*., 2018). Rabbitry is an emerging urban agricultural enterprise as an alternative source of animal protein in space constrained environment. Alarcon *et al*. (2017) reported that rabbit farming was gaining popularity in Nairobi city and was done by either individual farmers, groups or institutions such as schools who sell their animals directly to consumers or for own consumption. Alarcon *et al*. (2017) reported that these rabbits were fed on green weeds or grass harvested from roadsides. This concurred with observations in this study whereby rabbits were fed on vegetable remains, freshly cut grass and weeds sourced from nearby farms including those at roadsides.

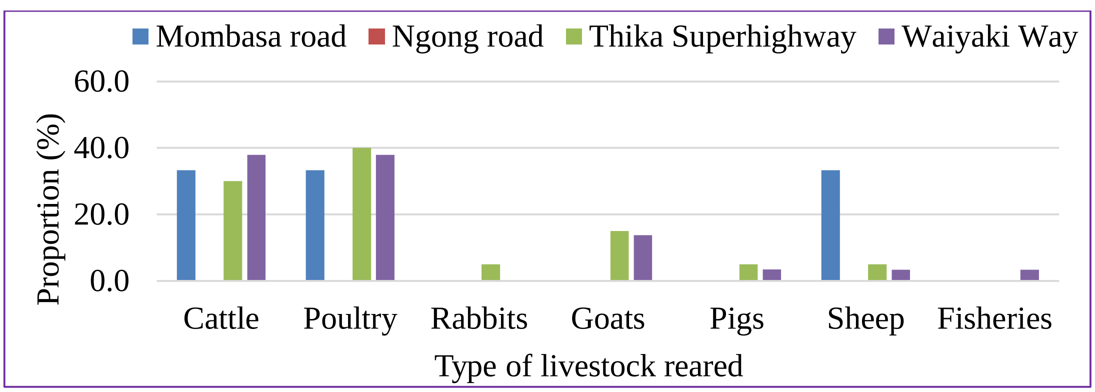

Figure 4. 13: Distribution of livestock along four major network links in Nairobi County, Kenya

Table 4. 10: Pearson chi-square test results for livestock reared across major network links of Nairobi County

Type of livestock	Chi-square value	*p*-value
Cattle	65.604	0.000
Poultry	4.751	0.191
Goats	22.250	0.000
Pigs	5.621	0.132
Sheep	2.415	0.405
Fisheries	8.477	0.037
Statistical test was done at 5% level of significance		

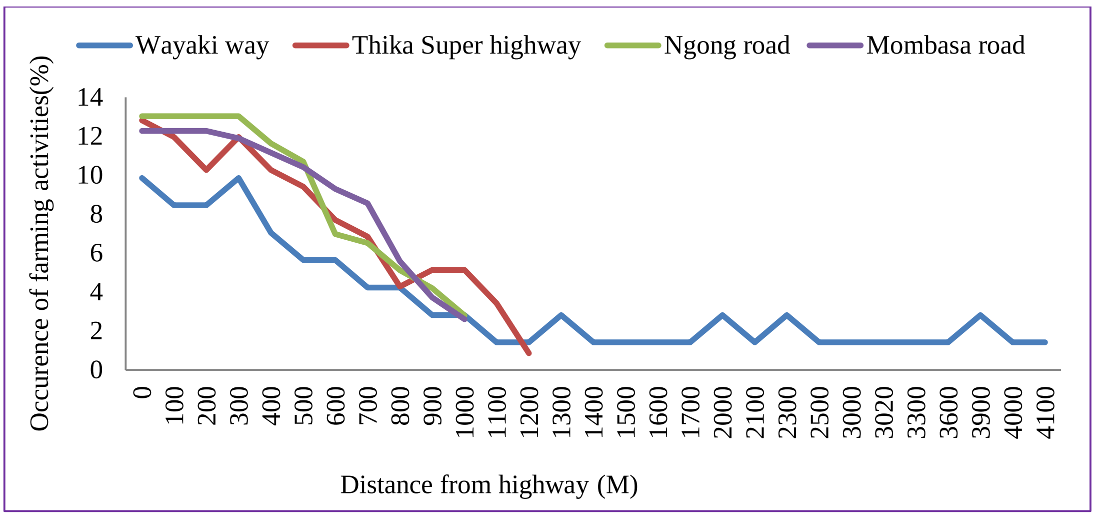

Figure 4. 14: Trend of intensity of farming activities with change in distance from junctions of the four major road transects in Nairobi County, Kenya

The intensity of farming activities across the four major network links of Nairobi County generally decreased with an increase in distance from the main road access points (Fig 4.14). This was so possibly due to the fact that most urban agriculture actors are usually found close to the main road access areas. Examples of these actors are the poor landless urban farmers who utilize any available nearby space such as road reserves to farm for survival in the city. These farmers are mostly in informal settlements which hosts about two thirds of the Nairobi's population. The Hungry Cities Partnership Report No.6 reveal that both the low and middle income earners in Nairobi County live in high-density areas located along the major network links (Owuor *et al*., 2017).

4.2.1.1: Occurrence level of farming activities along Mombasa road transect

One hundred and thirty two (132) farms were mapped on Mombasa road transect (Fig.4.15). More farming activities were undertaken at South C, General Motors and South B than the rest of other access links along Mombasa road.

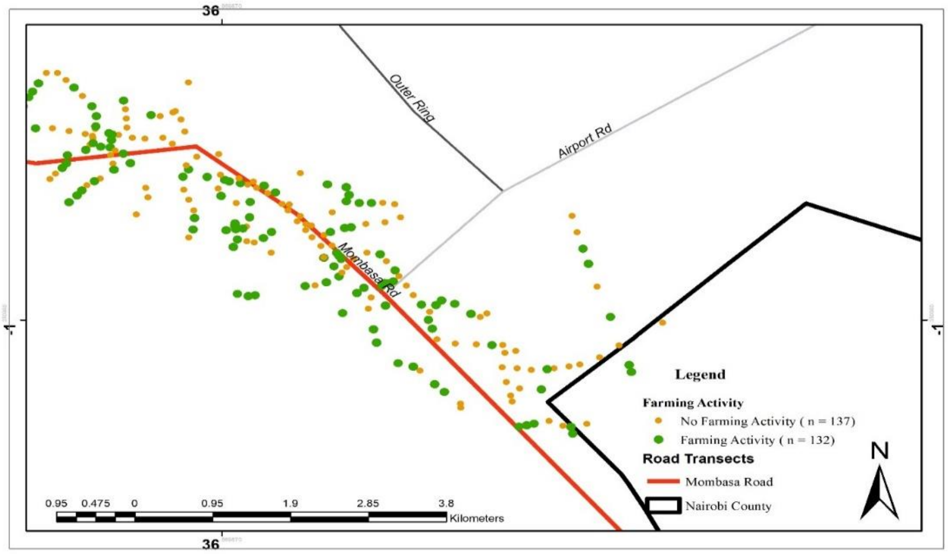

Figure 4. 15: Map showing the occurrence level of farming activities along Mombasa road transect. (Source: author, 2017)

The intensity of farming activities at various access points along Mombasa road transect generally decreased as one moved from the main road access point to the further interior (Fig 4.16). Fruit trees were substantially cultivated along this transect while fodder and oil seed crops were the least grown crops.

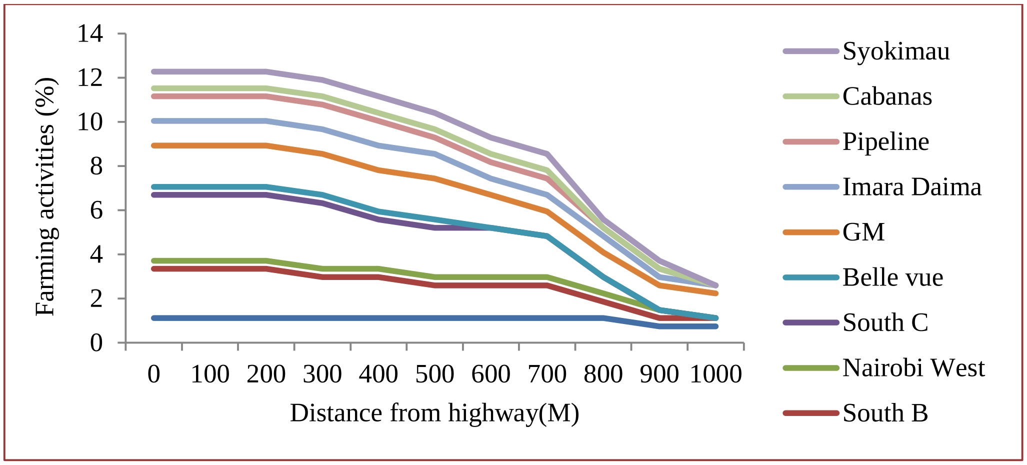

Figure 4. 16: Intensity of farming activities at access links along Mombasa road transect

Cattle, poultry and sheep were the only livestock found along Mombasa road transect at equal proportions (each at 33.3%) in enclosed structures (Plate 4.20) and open rearing (Plate 4.15). It is clearly evident that livestock rearing is increasing in various parts of the city. This is in agreement with Lee-Smith (2010) who stated that it is quite a common thing to find livestock being reared in Nairobi city. Alarcon *et al.* (2017) projected that the consumption of livestock products especially those from cattle, sheep and goat will double by the year 2038.

Plate 4. 15: Cattle, goat and sheep rearing off Mombasa road transect. (Source: author, 2017)

Plate 4. 16: Sheep rearing near JKIA off Mombasa road transect. (Source: author, 2017)

4.2.1.2: Occurrence level of farming activities along Ngong road transect

One hundred and three (103) farms were mapped along Ngong road transect (Fig.4.17). More farming activities were undertaken at Karen and Dagoretti than the rest of other access links along Ngong road (Fig 4.18).

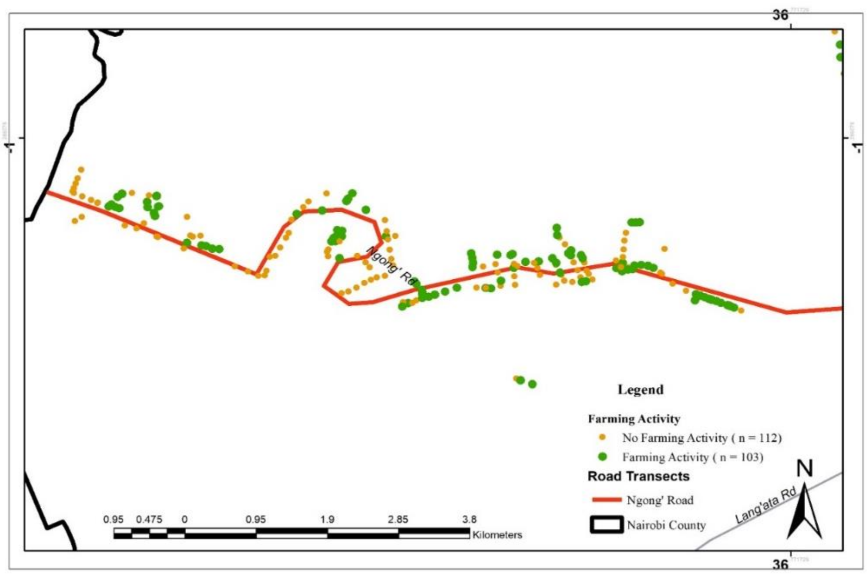

Figure 4. 17: Map showing the distribution of farming activities along Ngong road transect. (Source: author, 2017)

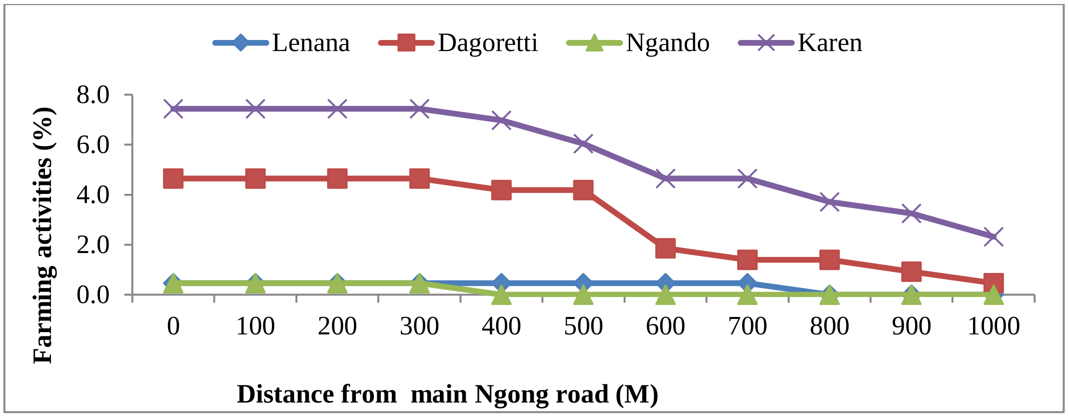

Figure 4. 18: Intensity of farming activities at access links along Ngong road

The intensity of farming activities along various access links along this road (Fig 4.18) generally decreased with increasing distance from the main road (0M) to the further interior (1000M). Ornamental plants (19.2%) and fruit trees (19.2%) were the major crop types cultivated along this road transect. There wasn't any livestock observed on this road transect during the period of survey. However, a study carried out in the year 2013-2014 by Dominguez-Salas *et al.* (2016) revealed notable livestock rearing around Dagoretti which is along Ngong road transect. Lee-Smith (2010) argues that livestock rearing plays a major role in the food security for urban residents of Nairobi County. This is so because farmers are able to supplement their diet with proteins from livestock products.

4.2.1.3: Occurrence level of farming activities along Thika Superhighway

Ninety eight (98) farms were mapped along Thika road transect (Fig.4.19). More farming activities were undertaken at Roysambu, Roysambu stage, Clayworks and Githurai than the rest of other access links under study along Thika Superhighway road (Fig 4.20)

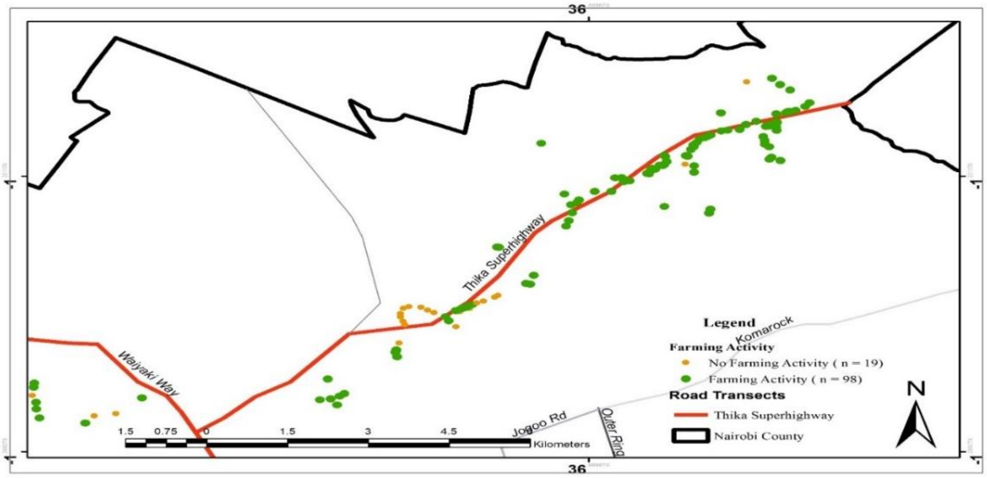

Figure 4. 19: Map showing the distribution of farming activities along Thika Super highway. (Source: author, 2017)

The intensity of farming activities at various access links along this road transect generally remained constant (uniform) as one moved from the main road (0M) to the further interior (1200M).

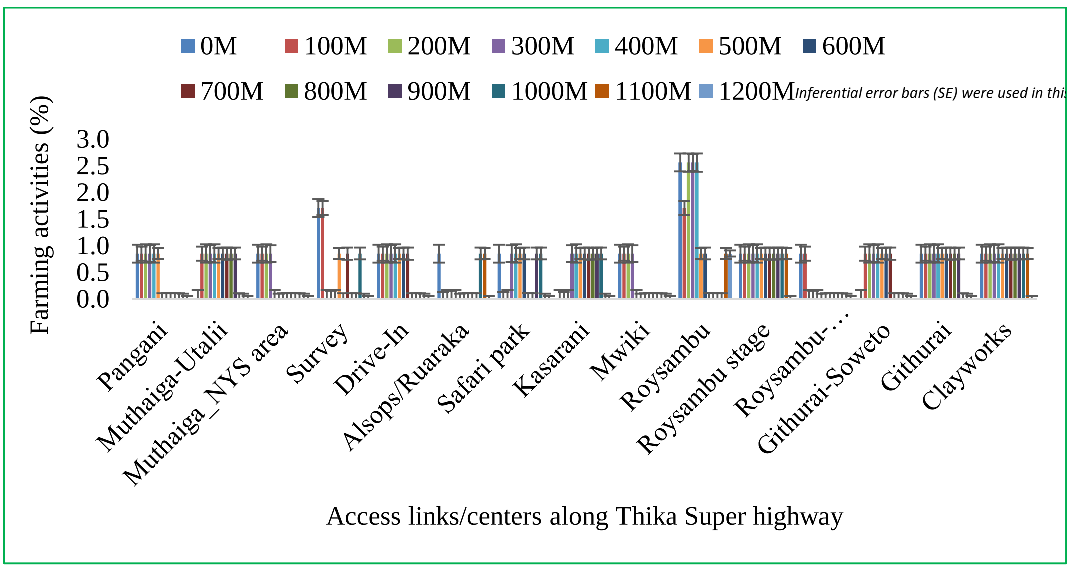

Figure 4. 20: Intensity of farming activities along access links along Thika Super highway

Vegetables (24.3%), fruit trees (17.8%) and roots and tubers (16.3%) were the major crops cultivated along this road transect while pulses and oil seed were the least grown crops. Poultry (40%) and cattle (30%) were the main livestock found along Thika Superhighway road (Plate 4.17; Plate 4.18). Rabbit rearing (5%) was only found off this road during the time of this study (Plate 4.19). It was a farming activity carried out by farmers at Mathare slum area. Small livestock such as rabbits occupy a very small space and consume little fodder especially the farm waste such as weeds and green vegetables such as kales. They are therefore best suited at built-up urban areas including the slums and are a great source of proteins and income for the urban poor. A study conducted by Owuor *et al.* (2017) indicated that rabbits were among the livestock reared in urban area of Nairobi County and were kept in cages at Makadara estate. Rabbitry is an emerging urban enterprise in Nairobi County. Alarcon *et al*. (2017) state that that small livestock such as rabbits are suited for space constrained environment and serve as alternative source of proteins. During this study, the rabbit keepers revealed that rabbit urine used as manure is very rich in nutrients for crops and they were selling it at high price to the interested neighboring farmers. Onono *et al*. (2018) state that livestock reared in Nairobi also provides manure for crop production. This shows that farmers are able to recycle and manage urban agricultural wastes.

Plate 4. 17: Types of poultry rearing in Sports View estate off Thika Superhighway transect. (Source: author, 2017)

Plate 4. 18: Cattle zero grazing in Garden City estate off Thika Superhighway transect. (Source: author, 2017)

Plate 4. 19: Rabbit keeping in Mathare estate off Thika Superhighway transect. (Source: author, 2017)

4.2.1.4: Occurrence level of farming activities along Waiyaki Way

Sixty one (61) farms were mapped along Waiyaki Way road transect (Fig.4.21). More farming activities were undertaken at Uthiru than the rest of other access points under study along Waiyaki way road (Fig 4.22). The intensity of farming activities at various access links along this road was uneven as one moved from the main road transect to the further interior. Vegetables (28.8%) such as kales, broccoli, cauliflower, lettuce and red cabbages and fruit trees (21.9%) such as bananas, avocado, and loquats were notably the major crops cultivated along this road. Ornamental plants (2.1%) and pulses (2.7%) were the least grown crops. Cattle (37.9%) and poultry (37.9%) were the main livestock recorded along Waiyaki Way road transect (Plate 4.20; Plate 4.21).

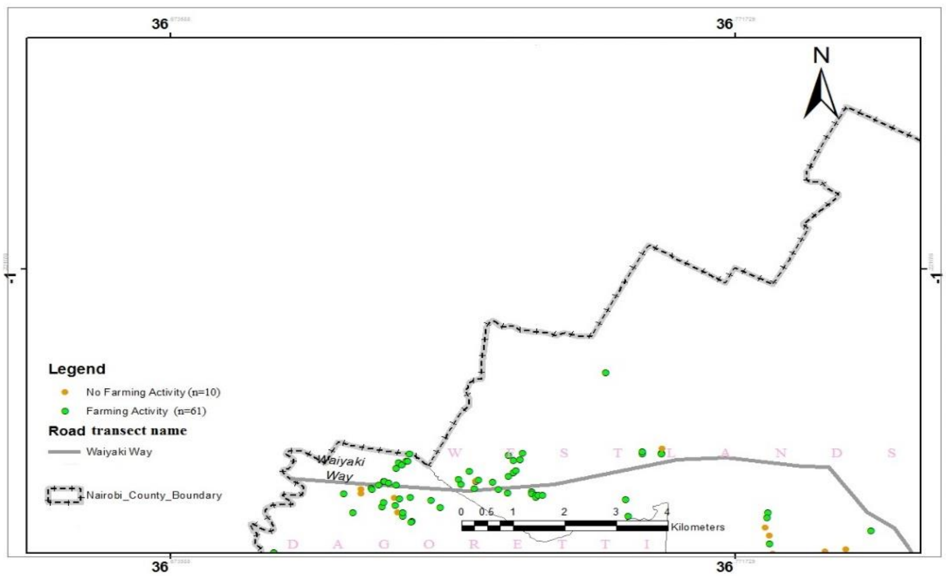

Figure 4. 21: Map showing the distribution of farming activities along Waiyaki Way. (Source: author, 2017)

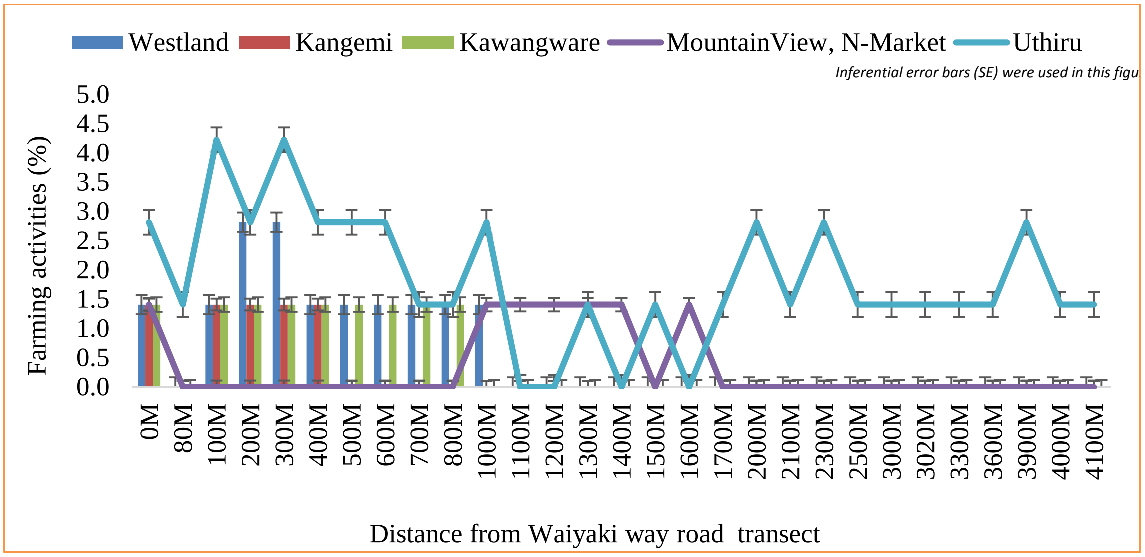

Figure 4. 22: Intensity of farming activities at access links along Waiyaki Way in Nairobi County, Kenya

Plate 4. 20: Enclosed and open cattle rearing at Kabete and Uthiru estates off Waiyaki Way transect in Nairobi County, Kenya. (Source: author, 2017)

Plate 4. 21: Poultry rearing in Highridge and Gichagi estates off Waiyaki Way. (Source: author, 2017)

Plate 4. 22: Goat rearing in Kagondo estate off Waiyaki Way in Nairobi County, Kenya. (Source: author, 2017)

Goat farming was mainly undertaken in pens utilizing limited space along the Waiyaki Way road access links (Plate 4.22) Pig rearing entailed use of permanent and temporary structures with feed being sourced from various sources (Plate 4.23). Past study indicated that insecure feed availability, insufficient sanitation and poor pig husbandry, as well as lack of sound veterinary services and meat inspection are factors that lead to poor animal, public, and environmental health (FAO, 2012).

Plate 4. 23: Pig rearing in Mountain View estate off Waiyaki Way. (Source: author, 2017)

Fish farming (3.4%) was only recorded along this road transect of all four transects (Plate 4.24).The fishponds were constructed using tarpaulin as liners to hold water. Fish farming in urban areas could be constrained by several factors including low production/productivity, limited supply of fingerlings, limited value addition, limited quality feeds and limited market access (Shitote *et al*., 2012). According to Opiyo *et al*. (2018), a growing number of contemporary urban centers are reusing treated and untreated waste waters for fish farming.

Plate 4. 24: Dam for fish farming at Kangemi estate off Waiyaki Way in Nairobi County, Kenya. (Source: author, 2017)

Majority of the farmers (>94%) did not subscribe to any farmer groups / associations across Waiyaki way and Thika Superhighway road transects (Fig 4.23). Along Mombasa road and Ngong road transects, membership subscription to farmer groups and associations was considerable (>20%) but still a minority. The most compelling reasons for farmer group subscriptions (Fig 4.24) were the demand by markets for consistency in provision of quality products and services (86%) and ability to get training opportunities from the associations (9%).

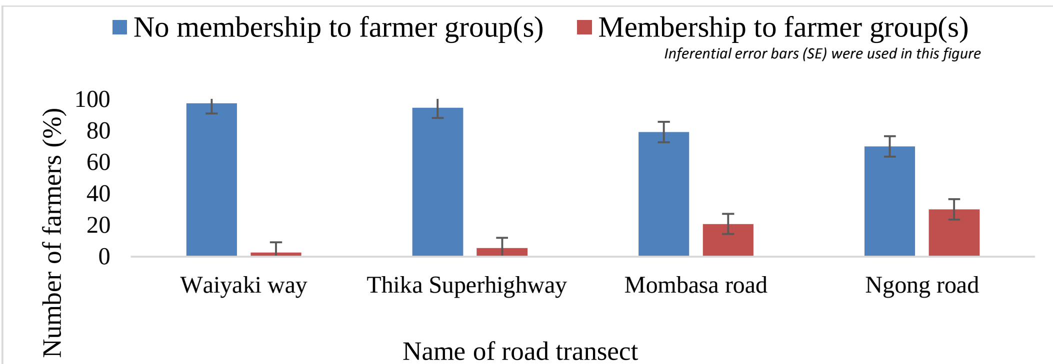

Figure 4. 23: Proportion of UPUA farmers belonging to farmer groups/associations along four major road transects in Nairobi County

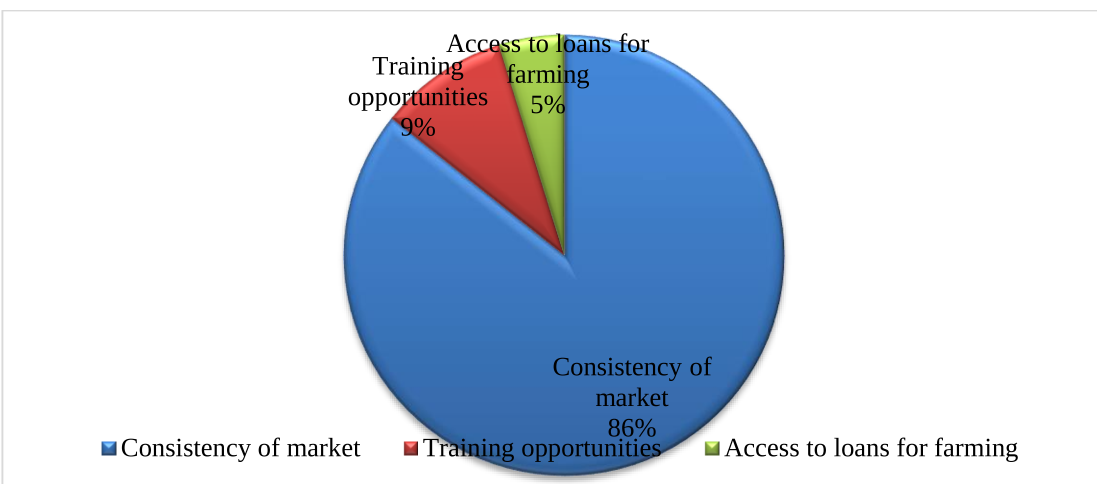

Figure 4. 24: Rationale for membership to farmer group(s) in Nairobi County, Kenya

The ominous challenges facing UPUA farmers along Mombasa road transect included scarcity of water, water pollution, scarcity and inaccessibility of manure for farming operations (Table 4.11). Along Ngong road transect the formidable challenges included unavailability/limited open space for farming, stiff competition in selling products, scarcity of water and manure for growing crops and rearing animals. At Thika Superhighway transect the disconcerting challenges included stiff competition amongst suppliers in selling of farm products, daunting task in owning land/open space, limited land/open space for farming, conflicts over land/open space, theft and destruction of farm produce by thieves and animals respectively. Along Waiyaki way the perilous challenges included theft of farm produce, expensive water and manure for farming operations, and unrivalled competition in selling of farm products.

Farmers along these road transects engaged in variety of crop production, despite the lamentations on challenges faced along the farming journey. This is a clear indication of how resilient an urban farmer especially the urban poor can be. Most city farmers venture into basic staple food production such as corn, kales, pulses, roots and tubers and bananas (Owuor *et al*., 2017). A study by Van de Lans *et al*. (2012) inform that yields from such individual crops are low because the poor urban farmer is unable to access some of the basis inputs such as fertilizer, pesticides, capital and clean water.

Table 4. 11: Type and magnitude of challenges faced by UPUA farmers along four major transects in Nairobi City County, Kenya

	Magnitude of the challenges (%)															
	Mombasa road transect				**Ngong road transect**				**Thika superhighway transect**				**Waiyaki way transect**			
Type of challenge	High	Medium	**Low**	**Total**	**High**	**Medium**	**Low**	**Total**	**High**	**Medium**	**Low**	**Total**	**High**	**Medium**	**Low**	**Total**
Water pollution	33.3	0	66.7	100.00	0	0	100	100.00	23	28.4	48.6	100.00	2.7	2.7	94.6	100.00
Water availability	69.60	8.70	21.70	100.00	60.00	10.00	30.00	100.00	11.7	7.8	80.5	100.00	5.3	2.6	92.1	100.00
Water affordability	0.00	0.00	100.00	100.00	20.00	0.00	80.00	100.00	9.8	5	85.2	100.00	11.4	2.9	85.7	100.00
Manure availability	68.20	9.10	22.70	100.00	50.00	40.00	10.00	100.00	26.6	6.2	67.2	100.00	5.4	0	94.6	100.00
Manure accessibility	55.00	10.00	35.00	100.00	42.90	14.20	42.90	100.00	27	12.7	60.3	100.00	5.4	0	94.6	100.00
Manure affordability	36.80	5.30	57.90	100.00	33.30	11.10	55.60	100.00	29.5	18	52.5	100.00	21.6	21.6	56.8	100.00
Open space availability	45.50	9.00	45.50	100.00	90.00	0.00	10.00	100.00	37.5	5.6	56.9	100.00	2.4	2.4	95.2	100.00
Open space ownership	25.00	0.00	75.00	100.00	0.00	0.00	100.00	100.00	46.5	7	46.5	100.00	2.4	0	97.6	100.00
Open space limited size(s)	23.50	0.00	76.50	100.00	75.00	12.50	12.50	100.00	46.4	10.1	43.5	100.00	20	20	60	100.00
Theft of produce	22.70	9.10	68.20	100.00	0.00	22.20	77.80	100.00	36.5	17.6	45.9	100.00	23.8	31	45.2	100.00
Land/space conflicts	28.60	0.00	71.40	100.00	0.00	0.00	100.00	100.00	28.5	3.2	68.3	100.00	0	2.6	97.4	100.00
Destruction by animals	5.30	5.30	89.40	100.00	12.50	50.00	37.50	100.00	29.6	21.1	49.3	100.00	12.2	41.5	46.3	100.00
Customers' perception	63.60	27.35	9.05	100.00	77.80	22.20	0.00	100.00	93.7	4.8	1.5	100.00	89.3	10.7	0	100.00
Competition for market	59.10	36.37	4.53	100.00	88.90	11.10	0.00	100.00	69.8	22.2	8	100.00	64.3	28.6	7.1	100.00

Farmers who were interviewed highly supported paradigm policy shift for UPUA in Nairobi County by recommending for the recognition, allowing and supporting UPUA by removing restricting laws on farming (50%) in order to increase food, employment and income (Fig 4.25). Other recommendations included allowing farming on open spaces (railway reserves, damping sites, undeveloped plots) even through renting of these areas (12.9%), supporting of farming groups and institutions with inputs (water, seeds, fertilizer) to improve their farming activities(11.4%) and zoning of land for UPUA (8.6%). A coherent legal framework that promote and regulate urban agriculture in Nairobi County was not there until after 2015. Since then, things have had a positive turn and UPUA has increasingly received the attention and support it so much needed. The Nairobi City County Urban Agriculture Promotion and Regulation Bill of 2015 is a clear indication that UPUA will be governed coherently by the city council. The bill was recently adopted as a bylaw and therefore its impact is yet to be felt as more reviews are being received for consideration.

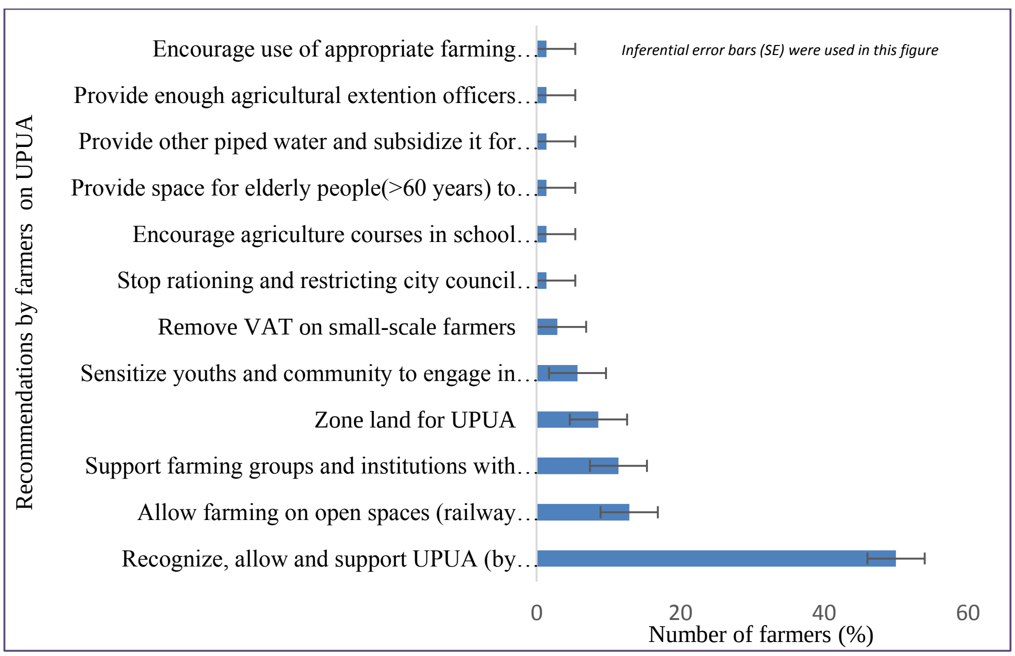

Figure 4. 25: Recommendations for UPUA policy development by farmers in Nairobi County, Kenya

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of the study

Urban and peri-urban agriculture has a very important role in urban centers and requires significant attention from various stakeholders. Nairobi city is urbanizing at an alarming rate and creating concern. UPUA in Nairobi city has an opportunity to improve the livelihoods (Lee-Smith, 2013) of the poor and therefore its research is worthwhile. Reliable data on the extent of urban/peri-urban areas being used for farming in Nairobi County, the spatial distribution of such areas, type of crops, animals and proximity to market places are lacking (Revi & Rosenzweig, 2013; Robineau & Dugué, 2018; Smidt *et al*., 2018

Ninety five (95) farms for the active farmers in Nairobi County were mapped in phase one. Fifty five (55) and forty (40) farms were mapped in the peri-urban and urban areas, respectively. In phase two for objective 2, 672 data points were visited and mapped on four road transects. 394 data points of the total had farming activities going on. On the 394 data points, 154 farmers were interviewed and 240 observations made on farms that had no farmer present at the data point for the interview at time of data collection. In total, 249 (95+154) farmers were interviewed and 489 (95+394) farms were visited for this study.

The findings showed a significant difference in size of land / space utilized by different crop production technologies. Crop production technologies of open field, multi-storey, micro garden and moist-bed were significantly (P=0.014) more on land/space (29.2%) which was less than a quarter of an acre. Open field technology was the most utilized crop production technology (26.6%) and was significantly (P=0.033) more in use at the peri-urban areas. Institutional land constituted the most significant (P=0.012) available land

(54.2%) and was heavily relied on in the urban areas. These study findings are in agreement with Githugunyi (2014) who reported that farmers adopted technologies which are land intensive in order to cope with inadequate land in highly populated areas of Roysambu ward in Nairobi County The intensity of farming activities generally increased with an increase of distance from access links/centers near the Nairobi CBD area to the further placed (outskirts) access links/centers along three major network links of Nairobi County. Fifty nine percent (59%) had farming activities going on among the major road transects. Crop enterprises were the major farming activity (slightly over 90%). These findings were similar with those of Githugunyi (2014) who observed that agricultural land use pattern in Nairobi metropolitan area would show zones of gradually increasing intensity from the built-up edges to where the city has no direct influence upon agricultural practice.

5.2 Conclusions of the study

The eleven crop production technologies utilized by urban farmers were widely distributed in the urban and peri-urban areas of Nairobi County. Open field (27%), the most utilized crop production technology was more preferred by farmers found in the peri-urban areas. Multi-storey garden technology (13%) was second and widely used in the urban areas. Privately owned land (28%) was mostly farmed on in the peri-urban areas. Institutional land (54%) was the most available land for farming especially in urban areas. However, farmers in the city were farming on small fragments of land/spaces of less than a quarter of an acre (39%). Crop production was the most prevalent agricultural enterprise. With the evidence of diminishing agricultural land and increasing of built-up areas, farmers in the city can adopt new and modern space-efficient technologies to continue producing food. Increased adoption and use of improved modern zero-acreage farming production technologies (e.g. integrated and rooftop gardens) can be embraced for increased UPUA.

Fifty nine percent (59%) of all respondents were actively involved in farming activities along the four major road transects in Nairobi County. Farmers' prevalence on crop production was 10x (91%) higher than that of mixed farming. The intensity of farming activities along the road transects increased with an increase of distance from the CBD. Thus the number of farms increased with increase in distance away from the built-up area to the peripheries of the city. Farming in urban and peri-urban areas of Nairobi County could improve livelihoods of urban residents if well supported and properly practiced. This could contribute towards the achievement of most of the sustainable development goals (SDGs). The attainable SDGs through UPUA are 1) No poverty: this could be possibly through employment and income earning from urban agribusiness. 2) Zero hunger: by providing safe, sufficient and affordable food which will end hunger, achieve food security and lead to improved nutrition. 3) Good health and wellbeing: nutritious food which could be derived from consuming a wide variety of food would give good health. 11) Sustainable cities and communities: UPUA could contribute in creating inclusive and resilient urban communities. The findings from this study would supplement Nairobi city planners' decision making process concerning urban and peri-urban farming, urban land use, space allocation and utilization of resources for increased UPUA.

5.3 Recommendations and further research

5.3.1 Recommendations

The departments of Agriculture and the Urban Planning need to seek ways for utilizing the institutional land for UA. This can be possible by collaborating with community members (especially the vulnerable - youth, women, persons with disability and low-income earners). Urban and peri-urban farmers can be sensitized to adopt improved production technologies and form groups to bargain for idle spaces for increased urban and peri-urban agriculture.

5.3.2 Further research

There is need for further studies to evaluate resource use efficiency (RUE) of the production technologies in order to promote those that are affordable and sustainable. That could lead to improved adoption by UPUA farmers and other stakeholders in Nairobi City County. Further research is needed to evaluate the use and sustainability of zero-acreage farming technologies such as rooftop gardens. This is due to the rapid urbanization and land use replacement which is leading to diminishing land available for UPUA and thus facing-off technologies such as open field production. Further studies are also needed to evaluate livestock production systems in urban and peri-urban areas of Nairobi City County. A study is necessary to cover more areas of the Nairobi City County.

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APPENDICES

Appendix I: Survey questionnaire for distribution of production systems

JOMO KENYATTA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY

FACULTY OF AGRICULTURE - HORTICULTURE DEPARTMENT

SURVEY QUESTIONNAIRE

Name of interviewer: Millicent Ogendi (Research Student)

Date…..……………

Study Objectives

This survey is being undertaken to collect data on distribution of production systems used in Urban and Peri-Urban Agriculture (UPUA) within the nine (9) districts of Nairobi County.

Informed Consent

As a good gesture to research ethics, I find it prudent that I ask for your consent. Consequently I am bound by the following;

a. Your responses will be treated with CONFIDENTIALITY.
b. The study DOES NOT intend to associate any of the responses in this questionnaire with you or your associates or your firm.
c. ANY divulgence if so occur, will be my responsibility.

By the above, will you accept to respond to the questions in this questionnaire? [   ]

01 Yes 02 No

SECTION 1.0 SOCIAL-ECONOMIC CHARACTERISTICS

1. Name…..……………………………………………………………………………

2. District/Sub county...Division…......................................

Location.......................................S/Location………...

3. Gender [ ]

01	Male	02	Female

4. Age bracket [ ]

01	18 to 35 years	02	36 to 50 years
03	51 to 65 years	04	Over 66 years

5. Highest level of education [ ]

01	Primary level	02	Secondary level	03	Certificate
04	Diploma	05	Degree		
06	Other (*specify*)................				

6. Occupation terms [ ]

01	Government sector-Permanent	02	Private sector- Permanent
03	Short-term Contracts	04	Casual
05	Business	06	Any other (*specify*)..........

7. How does income from urban and peri/urban agriculture contribute to your total income in percentage? [ ]

01 Less than 25% 02 25-50% 03 51-75%

04 More than 75%

8. Place of residence (within Nairobi)...

9. Marital status [ ]

01 married 02 single 03 Other (specify)…………….

10. Household size [ ]

01 1 to 3 members 02 4 to 6 members 03 7 to 10 members 04 10 members and above

11. Household head [ ]

01 male-headed 02 female-headed 03 child-headed

SECTION 2.0 PRODUCTION SYSTEMS

Note: Urban agriculture can be simply defined as agriculture practices within (urban) and around (peri-urban) cities, towns or metropolis.

12. How long have you been engaged in urban/peri-urban agriculture? [ ]

01 (less than 1 year) 02 (1- 2 years) 03 (3- 5 years)

04 (6-10 years) 05 (10-15 years) 06 More than 15 years

13. What type of production system are you practising? [ ]

01 Crops only 02 Both crops and livestock 03 Livestock only

14. Who owns the land you are using for farming? [ ]

01 personal land 02 family land 03 communal land

04 Institutional land 05 Unscheduled land 04 other land

15. How did you acquire the land you are using for urban agriculture? [ ]

01 Bought 02 Inherited 03 Rented

04 Other (*specify*)……………….

16. If bought, from whom? [ ]

01 Government 02 land buying company 03 individual
04 Other (*specify*)

17. If inherited, from whom? [ ]

01 Parent / guardian 02 sibling 03 friend

04 other (*specify*)…………………

18. If rented, from whom? [ ]

01 Institution 02 community 03 Individual

04 other (*specify*)……………

19. If other land, please specify which one [ ]

01 Road reserves 02 railway reserves 03 river banks 04 Forest reserves 05 neglected sites 06 other (*specify*)…

20. For the institutional land (*if applicable*) what are the requirements for its usage?

01 Through temporal licensing 02 local arrangement

03 other (*specify*)……………

21. For the unscheduled land (*if applicable*) what are the requirements for its usage?

01 City council licensing 02 arrangements with an organization 03 Arrangements with local administration 04 no licensing

22. What is the size of land used for your farming activities? (*Tick appropriately*)

	Approximated land size for crops	Approximated Land size for livestock
01 More than 2 acres		
02 1 to 2 acres		
03 ½ to 1 acres		
04 1/4 to 1/2 acres		
05 Less than 1/4 acres		

23. In your agricultural enterprises, what is the level of utilization (in percentage) for the crops grown?

Type of crop	Subsistence				Local market				Other (*specify*)			
	<25 %	25-50 %	50-75 %	>75 %	<25 %	25-50 %	50-75 %	>75 %	<25 %	25-50 %	50-75 %	>75 %
Local vegetables												
Exotic vegetables												
Herbs/spices												
Fruits												
Floriculture												
Legumes												
Cereals												
Other (*specify*)												

24. Farming technique and reasons

Farming Technique	Preference					
	cheap	High production	Easy to adopt	Environment friendly	Only option	Other (specify)
	01	02	03	04	05	06
Greenhouse [ ]						
Rooftop garden [ ]						
Balcony garden [ ]						
Vertical garden [ ]						
Wet garden [ ]						
Other (*specify*)						

25. What is the main source of water for your production? [ ]

01 Rain water 02 borehole 03 river water

04 City council water 05 other (*specify*)………………………………

26. What is the level of dependence (in percentage) of the source of water that you use for production?

Source of water	Frequency of usage for agricultural activities				
	81-100%	61-80%	41-60%	21-40%	>20%
Rain water					
Borehole					
River water					
City council water					
Other (*specify*)					

27. How do you manage agricultural wastes from the farming activities?

Waste type	Waste management							
	compost	Feed livestock	burn	sale	reuse	recycle	Dispose neighbourhood	Other (*specify*)
Crop waste								
Animal waste								
Waste water								
Other (*specify*)								

28. How many hours per day of your time are taken up by your farming activities? (*Where applicable, tick*)

a)Crop farming	Time spent (*in hours/12hr day)*				b)Livestock farming	Time spent (*in hours/12hr day*)			
	<2	2-4	4-8	8-12		<2	2-4	4-8	8-12

29. What are the main barrier / challenge to your farming activities if any?

01 Lack of access to capital 02 limited Land 03 Scarce water

04 Lack of technical support 05 City by-laws 06 Marketing

07 Public health issues 08 Any other (specify)...................

30. To what extent have the following challenges prevented you from developing urban / peri- urban agriculture activities? (*Where applicable, please record*)

Challenge	The extent it affects farming activities			
	Greater extent	Lesser extent	No extent	Not sure
	01	02	03	04

Access to capital [ ]				
Limiting Land [ ]				
Scarce Water [ ]				
Marketing [ ]				
Value addition [ ]				
Lack of technology [ ]				
City-by-laws [ ]				
Technical support [ ]				
Any other(*specify*) [ ]				

31. What is your perception of the surrounding public open space in regard to its usage? [ ]

01 it is well utilized 02 it is under-utilized 03 it could be used for agriculture 04 it could be used for other purposes

32. Do you relate with the urban planners from the city planning department? [ ]

01 yes 02 no

33. How do urban planners relate with you in regard to your farming activities? [ ]

01 They are supportive 03 they are intimidating 04 it is not clear

34. How do you want the law to be modified in order to favour urban/peri urban agriculture?

……………………………………………………………………………………………
……………

Thank you for your participation.

Appendix II: Survey questionnaire for occurrence level of farming activities along major network links

JOMO KENYATTA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY.

FACULTY OF AGRICULTURE

Questionnaire for: Study on 'determining occurrence level of farming activities across four major networks of Nairobi City County'.

Introduction: This is an academic research being conducted by a research scientist who is a member of JKUAT in the Department of Horticulture. The researcher invites you to participate in the exercise, whose objective is to determine occurrence level of farming activities across four major networks of Nairobi City County.

Informed consent: As a good gesture to research ethics I find it prudent that I ask for your consent to participate in the survey. Consequently, I am bound by the following:

- Your responses will be treated with CONFIDENTIALITY.
- The study DOES NOT intend to associate any of the responses in this questionnaire with you, your associates or your farm.
- ANY divulgence occurring will be my responsibility.

I agree to participate in this survey;

Signature of participant: ________________________ Date:

Please return the filled questionnaire to:	JKUAT, Department of Horticulture P.O. Box 62000-00200, Nairobi, Kenya	E-mail:

This questionnaire is being administered by enumerators. Please respond to only one questionnaire.

SECTION 1.0 SOCIAL-ECONOMIC CHARACTERISTICS

Presence of farmer	Yes [ ] Conduct interview.	No [ ] Answer the observational questions.

1. Name………………………………Tel……………………Road name………

2. District.......................................Division..

Location......................................S/Location..

Latitude……………………………Longitude……………Elevation………………

3. Gender Male [ ] Female [ ]

4. Marital status

Single [ ] Married [ ]

Divorced [ ] Widowed [ ]

5. Age bracket

18 to 35 years [ ] 36 to 50 years [ ]

51 to 65 years [ ] Above 66 years [ ]

6. Highest level of formal education

Primary [ ] Secondary [ ]

Tertiary [ ] None [ ]

7. Main Occupation

Government employee [ ] Private sector employee [ ]

NGO employee [ ] Business [ ]

Not employed [ ]

8. Gross income per month (ksh.)

Below 2000 [ ] 2000-10000 [ ]

10001-20000 [ ] 20001-40000 [ ]

Above 40000 [ ] None [ ]

SECTION 2.0 SPATIAL DISTRIBUTION OF URBAN AGRICULTURE

Note: Urban agriculture can be simply defined as agricultural practices within (urban) and around (peri-urban) cities, towns or metropolis.

9. How long have you been engaged in urban/peri-urban agriculture?

Less than 1 year [ ] 1- 5 years [ ] 6- 10 years [ ] 11-15 years [ ] More than15 years [ ]

10. What is your mode of engagement in urban/peri-urban farming activities?

Full-time farming [ ] Part-time farming – 75% [ ] Part-time farming – 50% [ ] Part-time farming <50% [ ]

11. Type of agricultural crop produce, level of production and use.

Crop produce	Production level					Use of crop produce	
	<25%	25%	50%	75%	100%	Home consumption	Selling
Kale							
Spinach							
Cabbage							

Managu							
Saga							
Cowpea							
Tomato							
Cucurbit							
Garden pea							
Beans							
Sweet potato							
Carrot							
Onion							
Dhania							
Leek							
Arrow root							
Potato							
Maize							
Fruit							
Ornamentals							
Other (specify)							

12. Type of space and requirements for its use for farming activities.

Type of space	Requirement for use			
	Temporal licensing	Arrangement with local administration	Local arrangement with institution	Not Applicable
Own land				
Rented house backyard				
Government land				
Institution land				
River bank				
Road reserve				
Railway reserve				
Under power lines				
Dumpsite				
Neglected sites				
Any other (specify)				

13. What is the approximate size (in acres) of the space you are farming on?

Less than 1/8 [ ] 1/8 to 1/4 [ ]¼ to ½ [ ] ½ to ¾ [ ] ¾ to 1 [ ] Over 1 acre [ ]

14. How will you rank the following challenges in relation to source of water for your farming activities?

i. Availability High [ ] Medium [ ] Low [ ]

ii. Pollution High [ ] Medium [ ] Low [ ]

iii. Cost High [ ] Medium [ ] Low [ ]

15. How will you rank the following challenges in relation to use of manure for your farming activities?

i. Availability High [ ] Medium [ ] Low [ ]

ii. Accessibility High [ ] Medium [ ] Low [ ]

iii. Cost High [ ] Medium [ ] Low [ ]

16. How will you rank the following challenges in relation to the space used for your farming activities?

i. Availability High [ ] Medium [ ] Low [ ]

ii. Ownership High [ ] Medium [ ] Low [ ]

iii. Size High [ ] Medium [ ] Low [ ]

17. How will you rank the following challenges in relation to security of your farm produce?

i. Theft High [ ] Medium [ ] Low [ ]

ii. Conflict of land ownership High [ ] Medium [ ] Low [ ]

iii. Destruction by livestock/wildlife High [ ] Medium [ ] Low [ ]

18. How will you rate your customer's perception when selling your farm produce?

High [ ] Medium [ ] Low [ ] I don't know [ ]

19. How will you rate the competition from other traders when selling your farm produce?

High [ ] Medium [ ] Low [ ] I don't know [ ]

20. Do you belong to any farmers'/ agribusiness group?

Yes [ ] No [ ]

21. Is the group of any benefit to you?

Yes [ ] No [ ]

22. If yes, what is your main benefit of being the group member?

Consistency of market [ ] Better selling price [ ] Access to loans for farming [ ] Better bargaining power [ ] Easy access to market [ ] Easy access to farm inputs [ ] Training opportunities [ ]

Any other……………………………

Thank you for your participation

Appendix III: Data sheet for recording GPS points, road transect name and farming activity type

FIELD SURVEY DATA SHEET

DATE………………SITE NO……………........GENERAL LOCATION……………………PERSONNEL…………………

MAIN ROAD NAME……………………………..ARTERIAL ROAD NAME………………....AREA NAME…………………

Interval: 100m	Farming activity: Y/N	Crop(s)	Crop technology	Livestock: Y/N	Specific Location (UTM)			Notes
					Easting	Northing	Elevation(m)	
0								
100								
200								
300								
400								
500								
600								
700								
800								
900								
1000								

Write further notes on back of sheet

Appendix IV: Paper publications

Ogendi, M. N., Mukundi, J. B., & Githiri S.M. (2021). Occurrence level of farming activities across major network links of Nairobi County, Kenya. *International Journal of Agronomy and Agricultural Research*, *18*(4), 25-37.

Ogendi, M. N., Mukundi, J. B., & Orege, O. O. (2019). Type and distribution of urban and peri-urban agriculture production technologies in Nairobi County, Kenya. *African Journal of Horticultural Science*, *16*, 1-12.

Ogendi, M. N., Mukundi, J. B., & Orege, O. O. (2014). Type and distribution of urban and peri-urban agriculture production systems in Nairobi County, Kenya. *In the RUFORUM Fourth Biennial conference, Maputo, Mozambique proceedings.*