EFFECTS OF FARM TECHNOLOGIES ON SWEET POTATO PRODUCTION IN MANYATTA SUB COUNTY, EMBU COUNTY

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DECLARATION

Declaration by Student

I hereby declare that this research project is my original work and it has not been presented for examination in any other institution of higher learning.

Signature: ……. **Date: ……**

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Declaration by Supervisors

This research project has been submitted for defense with my approval as university supervisors.

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DEDICATION

This research project is dedicated to my parents Mr. and Mrs. Muthuri, my sister Naomi, and brother Daniel for their love, moral support and encouragement through my studies.

ABSTRACT

This study is an investigation of Sweet potato (*Ipomoea batatas (L.)* Lam.) production technologies among smallholder farmers in Manyatta Sub County of Embu. The main problem behind this study is the growing importance of sweet potato as food security crop and the very little attention it receives at policy level. Several technologies exist that can enhance production and the study sought to assess the extent of use of these technologies which include; irrigation, ridging, the use of certified vines and fertilizer application. The objectives of the study were; to identify the production technologies currently being used, to investigate the challenges to sweet potato production and to assess the effects of sweet potato production to households in Embu County. The study was carried out in 10 sweet potato growing sub locations within Manyatta, which included Dallas, Kamiu, Njukiri, Nthambo, Kiangima, Itabua, Mbuvore, Manyatta, Gatunduri, and Kithimu in Nembure division. Using a case study research design, purposive and random sampling of sweet potato growing farmers, and through the use of questionnaires, interviews and observation as sources of data, the data was collected from a sample of 381 sweet potato growing farmers. The study observed that adoption decisions were influenced by socioeconomic (age, gender, education, farm size), ecological (agro ecological zones, temperature, rainfall, altitude, pH of soil/ water) and institutional factors (extension services from government and NGOs). The analytical tools included cross tabulation, simple correlation and the use of percentages. The findings of the study show that most farmers had adopted improved varieties (Bungoma, Kenspot 2, 3, 4 and Kemb 10 which are high yielding, highly consumed, early maturing, resistant to drought, pests and diseases) therefore increasing yield. Hypothesis test showed that ‘there is a relationship between the technology applied and the sweet potato yield. The study also found out that, setting up community managed nurseries; including knowledge on rapid multiplication techniques and quality maintenance of planting materials were the key for sustainability. The study concluded that adoption of modern technologies was crucial for sweet potato production. This increased yield and provided a supplementary source of income and food self-sufficiency. The study recommended that more research work to be carried out on sweet potatoes, empower farmers on value addition for their products as this would change their attitude towards economic viability of sweet potato production and create avenues for easier access to clean planting material.

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ABBREVIATION

ASALs	Arid and Semi-Arid Lands
CGIAR	Consultative Group for International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center
CIP	International Potato Center
CIRAD	French Agricultural Research Center for International Development
GoK	Government of Kenya
IFPRI	International Food Policy Research Institute
IPA	Innovations for Poverty Action
KALRO	Kenya Agricultural and Livestock Research Organisation
LM	Lower Midland
LH	Lower Highland
LH1	Lower Highland 1
MOA	Ministry of Agriculture
NARS	National Agricultural Research Systems
NEMA	National Environmental Management Authority
NGOs	Non-governmental Organisations
OFSP	Orange-Fleshed Sweet Potatoes
pH	Power of Hydrogen
PRSP	Poverty Reduction Strategies Paper
R&T	Roots and Tubers
SPFMV	Sweet Potato Feathery Mottle Virus
SSA	Sub Saharan Africa

UM	Upper Midland
UM2	Upper Midland 2
UM3	Upper Midland 3
UM4	Upper Midland 4
UNDP	United Nations Development Program
UNFAO	United Nation’s Food and Agriculture Organization
UNCTAD	United Nations Conference on Trade and Development
WFP	World Food Programme

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

"United Nation's Food and Agriculture Organization (FAO) (1990, 2011) stated that sweet potato (*Ipomoea batatas (L.*) *Lam.*) is an imperative crop in the developing world and a traditional, but less important crop in some parts of the developed world. It remains the seventh most essential food crop - after wheat, rice, maize, potato, barley and cassava"- with over 105 hundred million metric tonnes of foodstuffs in the globe annually (FAO, 2011). China is the world's largest producer with a yearly aggregate of 80 to 85% whereas the remaining states in Asia have the subsequent main production, followed by Africa and Latin America (Centro Internacional de la Papa, 2009).

It has a significantly unrealized potential and is capable of generating high yield of dry matter in each unit area of acreage and labour, and this potential is achievable under varied agro-climates including ASALs and agricultural systems. It adapts to a wide range of uses: food, feed and serve as raw materials for both food and feed based industries. Global production is concentrated in 15 countries, accounting for nearly 97% of entire world yield (FAOSTAT, 2006). A rapid population growth in the 1980s, causing severe pressure on agricultural land, is reflected to be a principal influence for the prompt increase of production in numerous nations, precisely in Vietnam, Kenya, Rwanda, Burundi, North Korea and Madagascar. Africa's major producers are: Uganda: 1.9 million tons, Rwanda: 0.7, Burundi: 0.68 and Kenya: 0.63 (FAO, 2006).

According to FAOSTAT (2006), "yearly sweet potato production in Africa has improved moderately from 11.6 million tonnes in 2002 to 12.9 million tonnes in 2006. It projected that West-, East-, Central- and Southern Africa had an yearly production of 4.2, 7.2, 1.2, and 0.5 million tonnes, respectively." Globally, it is the second most economically significant root crop after potato in addition as a vital food security crop in the poorest areas of the globe as well as Sub-Saharan Africa (SSA). They are remarkably essential relative to cereals in Africa covering an estimated 2.1 million hectares having a yearly projected production of 9.9 million tonnes of roots (Stathers, 2005).

The crop is mainly essential in countries adjacent to Lake Victoria, in East and Central Africa, a co-staple in Rwanda, Burundi, and Uganda and plays a crucial role in food security in Kenya, Tanzania and D. R. Congo. Conventionally it has been grown on a small scale as a

secondary food crop in SSA, and is critical for food security during shortage of other foodstuffs owing to prolonged drought and more catastrophes. "Its adaptation to marginal environs, role to domestic food security and flexibility in diverse agricultural systems brand it an imperative component of policies to aid the rural poor advance their incomes. As it only requires a short maturity period, it is able to provide food in regions with short rainy times and persistent drought where other crops are not able to survive" (Stathers, 2005).

It is a key root crop in East Africa and critical to subsistence farmers and rural households; the roots act as an energy source and vitamins while the vines provide nutritive forage. The yield in Africa is less than one-half the global average. Sweet potato feathery mottle virus (SPFMV) disease results to harvest losses of up to 80% (Wambugu, 2003). Major root and tuber crops grown in Kenya include: Irish potatoes, Cassava, Sweet potatoes, yams and cocoyams. Sweet potato production in the year 2008 amounted to 3,808,000 tonnes valued at 23 billion Kenya Shillings. They have grown increased significance owing towards their role in food security, ability to tolerate drought as well as their potential for marketable processing. Past efforts towards improvement of the root and tuber crops in Kenya have mostly focused on improvement of high yielding varieties that are pests and diseases tolerant (GoK, 2010).

The challenges that still face the sub-sector include; inadequate research and development; low production levels of quality seed and planting materials; low productivity, weak research extension-farmer linkages, low level value addition and processing; and poor market infrastructure. In addition, the industry has inadequate financing and credit services; and there is poor enforcement of produce and product standards. The dissemination and adoption of new technologies continues to be poor, and there is unfavorable and ineffective regulatory framework. These shortcomings have resulted in poor performance of the root and tuber crops industry (GoK, 2010). Research studies conducted on sweet potato production in Embu County have looked at varieties for farmer preference (Ngoroi *et al.,* 2013). This study focused on sweet potato production technologies. It is the main root and tuber crop grown in Embu County.

1.2 Statement of the Problem

Lack of sufficient clean planting materials is the major challenge to sweet potato production in Kenya owing to their slow proliferation rate and poor agronomic practices (Githunguri *et*

al., 2004; Odendo *et al.,* 2001). The available empirical studies in Kenya have paid extra importance on cultivar improvement than on cultural practices thus requiring research programmes to begin tackling agronomic necessities and rapid reproduction and dissemination of certified vines. It becomes problematic during the start of the planting time, as the persistent dry period is normally preceded by scarcity of vines. The end result is delayed planting leading to minimal chance to select certified young vines for planting. This has effects for both pest and disease accumulation through infested vines (Stathers, 2005).

Limited early-maturing sweet potato varieties are found in East Africa, and because of the postponed planting the crop develops when the rains have subsided causing the topsoil around the roots to dry leading to cracks that predispose the roots to *Cylas weevils* (Stathers, 2005). Multiplication to renew farmers' planting materials is being conducted by the Ministry of Agriculture and by Non-governmental Organisations but the supply is still inadequate. "Numerous strategies intended at solve vine inadequacy and extension lead food production and security has been placed by the Kenya Agricultural and Livestock Research Organization (KALRO) and International Potato Center (CIP)." Access to certified vines of improved varieties for vegetatively grown crops remains the key challenge to Kenyan farmers (GoK, 2010).

Manyatta Sub County's main economic activity is Agriculture, which is the economic pillar of Embu County. Majority of the people in the County depend on this sector for their livelihood, most of it being peasant (small-scale) farming. In fact, the Kenya Agricultural and Livestock Research Organisation (KALRO) carry out research at the heart of the County. Sweet potatoes are one of the main root and tuber crops grown by small-scale farmers within Manyatta. Most farmers at the grassroots level have not been able to access proper production technology like certified planting materials of improved sweet potato varieties. This is because of the absence of formal seed systems for producing and distributing quality vines. More research is required in order to improve the quality and yield in sweet potato production.

Although many studies have been done on sweet potato production in Manyatta, little information exists on the effects of farm technologies on sweet potato production. Most of the studies and research done (Wambugu, 2003) has concentrated on the improvement and transference of tissue cultured virus resilient sweet potato variety, while others focused on varieties for farmer preferences and very little has been done on production technologies at

households' level. This study filled this gap by investigating the effects of farm technologies on sweet potato production in Manyatta, Embu County. It was achieved by identifying the production technologies used, looked at farmer awareness and adoption levels of the various technologies.

1.3 Research Questions

This study addressed the subsequent research questions:

1. Which technologies are currently being used for sweet potato production in Embu County?

2. What are the challenges to sweet potato production in Embu County?

3. What are the effects of sweet potato production to households in Embu County?

1.4 Objectives of the Study

1.4.1 General Objective

General objective was to investigate the effects of farm technologies on sweet potato production in Embu County.

1.4.2 Specific Objectives

1. To identify the production technologies currently being used in Embu.

2. To investigate the challenges to sweet potato production in Embu.

3. To assess the effects of sweet potato production to households in Embu.

1.5 Study Hypothesis

1. H_0: There is no relationship between the technology applied and the sweet potato yield.

1.6 Justification of the Study

Root and tuber crops (Sweet potatoes) are high yielding crops that can grow in diverse environments including the ASALs, thus providing a great potential for ensuring food security for the majority of Kenyans. Moreover, the current longer and drier conditions in all agricultural areas attributed to global warming, has led to a reduction in cereal production but

the hardy root and tuber crops can effectively substitute them. In spite of the potential for these crops to address food security, a significant proportion of rural communities in Kenya are constantly faced with food deficits. This is because, apart from Irish potatoes, utilization of these foods is low as throughout history, at least in Europe and the near East has generally perceived it as poor man's food. This has impacted negatively on the efforts to promote them as viable and commercially marketable foods (GoK, 2010).

Furthermore, the growth of the livestock sub-sector has largely relied on the availability of by-products from the cereal milling industry. However, the high cost and scarcity of cereals and consumption of whole maize grain denies the animal feed industry the by-products thus increasing the cost of feeds. Sweet potato products can effectively substitute cereal products used in animal feed formulations. Additionally, these crops have lacked appropriate policies to spur their development due to historical reasons. In Kenya, lack of appropriate policies on traditional crops find its roots all the way to the colonial days when agricultural policies were geared towards supplying Britain and European markets with raw materials for industry as well as food production for the Kenyan settlers. As a consequence, the colonial agricultural policies neglected both the traditional technologies and traditional crops among which are the root and tuber crops (GoK, 2010).

There is little investment on research and development of local crops despite their potential in the food, feed and industrial products. As a result, varieties of these crops remain low yielding with inconsistent quality and susceptible to pests and diseases. Marketing of these crops is also not organized (GoK, 2010). It is hoped that, this study will shed light on the need to innovate and acquire modern appropriate agricultural technologies, in order to deal with the current situation effectively, and may thus result in the formulation of appropriate strategies by the governments, on ways of ensuring use of modern technologies that will benefit government planners, policy makers, business entrepreneurs, researchers and farmers thus leading to food security in Kenya and East Africa.

1.7 Scope and Limitations of the Study

The study focused on effects of farm technologies on sweet potato production in Manyatta Sub County of Embu County, Kenya. Further, it was limited to only sweet potato growing farmers in two sub counties i.e. Embu West (Central and Nembure Divisions) and Embu North (Manyatta Division) within Manyatta Sub County, where agriculture is the backbone

of the economy. The region was chosen since it represented sweet potato production zones within Embu. This study mainly focused on 10 sweet potato growing sub locations, which included Dallas, Kamiu, Njukiri, Nthambo, Kiangima, Itabua, Mbuvore, Manyatta, Gatunduri, and Kithimu in Nembure division. The study specifically focused on sweet potato production technologies, which included: irrigation, ridging, use of clean planting materials of improved varieties and fertilizer application.

The study gave the general picture of other sweet potato production technologies accepted by growers nationally. The research was carried out for a period of three months between May and July 2015. Only sweet potato growing farmers were interviewed to meet the study objectives. The researcher met some constraints during data collection. Research was carried out under financial constraint because of insufficient resources. The data was therefore collected from 10 sub-locations that mainly grew sweet potatoes. Selected farmers were unable to respond to some of the questions due to illiteracy. The researcher overcame this by supplementing the information given by farmers by interviewing key informants representatives from the "Kenya Agricultural and Livestock Research Organisation (KALRO) and Ministry of Agriculture (MoA)".

1.8 Operational Definitions

Agronomic Packages: In this study entailed the use of improved varieties, clean planting material, planting time, fertigation, pest and diseases**.**

Cultivars: Are short cultivated selections. They are plants propagated vegetatively.

Farm Technologies: In the study farm technologies entailed sweet potato production technologies (irrigation, ridging, fertilizer application, use of clean (certified) planting materials and improved varieties).

Sustainable Agriculture is the production of plant foods using agricultural techniques that safeguard the environment, public health, and human populations.

Clean Planting Materials are younger vine parts free from pest and disease attack.

Power of Hydrogen (pH) is a measure of the acidity or alkalinity of the soil.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter involves review of previous empirical studies. It looks at the existing gaps in previous research globally, regionally (Africa) and specific area of study (Manyatta Sub County, Embu County).

2.2 Sweet Potato - History and Development

Sweet potato (*Ipomoea batatas L.*) which is unknown in the wild state, originated in the region that extends from the south of Central America to the north-west of Latin America. It was introduced into many areas of Africa through the impetus given by the Portuguese navigators in the 16th Century. It is an essential root crop grown throughout tropical and warm temperate regions with adequate water to sustain its development, and needs light textured topsoil with an optimal pH of 5.5-6.5 and temperature between 21-26^{o}C (Ramesh *et al.,* 2010). Sweet potato can be grown in wide range of agro ecological zones including low rainfall marginal lands and has low input demand. Due to its drought tolerance, it serves as a food security crop with a high nutritive value. The orange-fleshed sweet potato varieties offer regular supplies of Vitamin A, and can be processed into juice or composite flours for baked products and weaning foods. The leaves are used as a vegetable and the vines as animal fodder (GoK, 2010).

2.2.1 Health and Nutritional Benefits

Owing to health concerns by the customers and the consequent enhancement of its nutritive d importance in some varieties, its utilization as food and breakfast is on the rise in the city. The orange fleshed varieties contain Vitamin C and beta- carotene (Vitamin A) which helps build immunity in children, prevents blindness and prevention against cancer-causing free radicals (GoK, 2010). In the northern United States, humans only consume the sweet potato. In the southern United States, it is used in regional cuisines, and a large part of the crop is fodder (Huntrods, 2013). Current investigation has concentrated on improvement of high starch, high dry matter and coloured (ß-carotene and anthocyanin-rich) sweet potato varieties for manufacturing applications and its use as food and livestock feed (Ramesh *et al.,* 2010).

This crop is largely grown by women mainly for family use and supplementary household income (Kapinga, 2004 and Gibson *et al.,* 2007; Katan and De Roos, 2004; FAO, 2011). This ability to form ground cover quickly allows suppression of weeds such as striga, prevents erosion and preservation of soil fertility. Consequently, it is an attractive crop for Kenya's agriculture. Utilization has been pronounced to deteriorate as salaries increase - a change often associated with development, comparatively since it is professed at least in Europe and the near East as a "deprived man's food" (FAOSTAT, 2008; Centro Internacional de la Papa, 2009). A practical methodology to realize the aim of sweet potato product improvement is to add the nutritive content of this vastly utilized crop. It less laborious and uses small quantities of inorganic fertilizers (Ministry of Agriculture, 2002- 2010).

The increasing dependency in unindustrialized nations on imported corn is unsustainable and the tendency ought to be reversed by stimulating dependence on native crops, precisely roots and tubers. The significance of these crops as a worldwide basis of carbohydrates is well recognized. Unfortunately, study and improvement on roots and tubers is partially inclined towards pre-harvest production only, particularly genomic enhancement. An incorporated policy of production, processing, and marketing is mandatory to inspire improved consumption and institute in developing nations the full potential of these crops, predominantly with reference to their influence to food self-sufficiency (FAOSTAT, 2001). Roots and Tubers are greatly essential food crops in Africa yet the existing proof of research on these food crops is scanty. Various crops have been branded "orphan crops", as little concern was given by colonial powers and, originally, by the global donor community to advance them (Maredia *et al.,* 1998; Low *et al.* 1997; Spencer and Associates 1997; Woolfe 1987, 1992, Scott *et al.,* 2000).

2.3 Empirical Studies

According to the International Potato Centre in Lima, Peru report (2009), Peru preserves the major bank of sweet potato genetic factor globally. More studies in Lima documented that the sweet potato offers 2 to 3 times more starches than maize. A research conducted by the French Agricultural Research Center for International Development (CIRAD) in France (2012), acknowledged a crossbreed called "Africa" and was a great achievement; retailed in urban African markets. It had short maturity period of 12 to 16 weeks, value-added produce with numerous roots and a very high resistance to disease, shelf life of 4 weeks which pleased

consumers (UNCTAD, 2012). In Vietnam, sweet potato statistics exhibited a great chance for improved productivity from sweet potato was in more effective and efficient usage of current technologies (CIP, 1999- 2000).

Attaluri (2013) suggested that sweet potato is grown during the rainy season and mainly eaten in India. Total sweet potato production was high but its yield (t/ha) was low. Accessibility of certified vines on sustainable base was the main issue. He further recommended that plans needed to be put in place to enable that certified vines are obtainable all year round. According to Fuglie *et al* (1999), the establishment of certified vines for clonal crops has lessened poverty by raising crop output, through enhanced seed value and distribution of upgraded varieties and related pro-poor characteristics.

Previous study prepared in South Africa has proven that the nutritive value in sweet potatoes can be enriched by producing novel varieties from existing germplasm. Oke & Workneh (2013) further advised that postharvest handling and storing of sweet potatoes require more exploration on the means by which the novel cultivars can be utilized for manufacturing and trade purposes. According to Low *et al* (2007), a study in Mozambique on Orange-fleshed sweet potato (OFSP) was evaluated with the purpose to increase vitamin A intake and serum retinol concentrations in infants. It is highly nutritious food and has been shown to have specific health benefits, provides energy and drought resilient making it an exceptional food security crop. Recent experiment in Mozambique shows that acceptance of OFSP is limited by obtainability of vines and concentration of extension service (Mazuze, 2005).

Mbanaso *et al* (2012) evaluated the degree of acceptance of sweet potato invention technology by growers in the Southeast agro-ecological zone of Nigeria. The results revealed 79.63% were cognizant of the technology, 20.37% were not. He also went further to highlight the limits to improved acceptance of the technology as lack of land, difficulty in assimilating sweet potato production technology into prevailing production system, low customer preference linked with sweet potato products, absence of market, inaccessibility of sweet potato vines, their high price and unobtainability of agrochemicals. It endorsed the improvement of less complex technologies by investigation. A study by Ezeano (2010) identified animal and mineral enricher as the technologies that were mainly used for production in Southeastern Nigeria.

A comprehensive research report on the role of the sweet potato in Uganda by (Bashaasha *et al*., 1995) highlighted a number of important constraints to both production and post-harvest. Most notably the report highlighted the fact that "sweet potato is perishable with a very short shelf-life postharvest storage is virtually non-existent". Evidence suggested that the process of piecemeal harvesting may be a form of cultural pest control for sweet potato weevil (Smit, 1997). According to Namanda *et al* (2013*)*, dry spells in Bukedea and Soroti districts in Uganda result to sweet potato vegetation drying up, leading to problems in obtaining certified vines as the rains start predisposing vulnerable rural families to hunger before the grain harvest. Recent survey evidence by (Fuglie, 2006, 2007) in Uganda specifies that the absence of sustainable seed systems is the basic limitations to enhancing sweet potato efficiency in Sub Saharan Africa (SSA).

In a study on the diffusion of enhanced sweet potato varieties and tools for handling, storing and consumption among smallholder growers in Rangwe Division, Homa Bay County in Kenya, Obonyo (2004), found that technologies adopted increased sweet potato yield thus improving domestic food security and vigor of target communities. Its resolve was to develop nourishing status and household salaries by increasing their access to high yielding beneficial varieties. Research in Kenya established that female growers were probable to accept the OFSP if the genetic copy were adequately rich in starch, low in fiber, and if they were familiarized through community training programmes that concentrated on the wellbeing of infants (Hagenimana & Oyunga, 1999). According to Wambugu (2003), major restrictions to production in Kenya comprise the extensive usage of low yielding and late-maturing outdated varieties and shortage of certified vines. Further constraints are lack of an appraising and selling policy with Sweet Potato Feathery Mottle Virus (SPFMV) disease and weevils being the most significant (Wambugu, 2003). Even with chromosomal alteration and other technologies transmitted, much energy is compulsory to improve dissemination channels to reach small-scale farmers.

Studies by Ngoroi *et al* (2013) for example, conducted on sweet potato production in Embu County have looked at varieties for farmer preference. Farmers in Kithimu location in lower part of Embu County evaluated three varieties of sweet potatoes. The varieties evaluated were KEMB 10, ExSimba and Bungoma. Farmers gave taste as the most important criteria for sweet potato selection followed by texture and maturity period. This was followed by ease of cooking, root size, appearance and yield while skin colour was of least importance. The

recommendation given is that more work should be done using more farmer clusters spread across the target zone and consider more socio-economic issues like different gender in the adoption process (Ngoroi *et al.,* 2013).

2.4 Gaps in Literature

The increasing of food insufficiency in Kenya has steered planters living in the highlands of Central Rift Valley, and Eastern Kenya (Embu, Meru) to demand sweet potato vines. Conversely, several farmers have accidentally collected vines that are of low quality and not subjected to tuberization in the cool high potential highlands leading to dissatisfaction and anguish when the crop is required for nourishment (Maling'a *et al.,* 2013). This study acknowledges that there are gaps in literature review on sweet potato production and technology use. One of the major gaps identified is that sweet potato variety improvement has been done without associated agronomic packages. This study sought to fill this gap by investigating the types of technologies currently in use and the level of adoption by farmers. This study also sought to comprehend the absence of certified planting vines; tested the likelihood to proliferate the quantity of planting material using fertilizer to increase the vines production in the study area (Manyatta, Embu County).

2.5 Theoretical Framework

2.5.1 Technology Adoption and Diffusion of Innovations Theory

"Diffusion is the practice where an invention is transferred over definite channels over a period between participants of a group (Rogers, 2003). The sweet potato farmers replaced planting the vines on flat ground with ridging as this increased yield by producing larger tubers. An invention is an impression, practice, or item that is professed as original by an individual or other entity of acceptance. "Key components in the dissemination of novel concepts are the invention, communication channels, time and the social system". Novelties in this study are the farm (modern) technologies for sweet potato production. The technologies used are irrigation, ridging and the use of certified vines of improved varieties (Rogers, 2003).

Sweet potato production has increased over the years globally due to its growing importance as a food security crop. Sweet potato farmers who had adopted modern technologies and seen

the benefits mainly influenced technology adoption by fellow sweet potato growing farmers in Manyatta (early adopters). The social system entailed farmers, farmer groups, and institutions like "the Kenya Agricultural and Livestock Research Organisation", Ministry of Agriculture and Non-Governmental Organizations. According to technology adoption theory, agricultural technologies can be beneficial to one farmer and not the neighbor. This is because of differences in credit access, household specific labour constraints as sweet potato is largely grown by women. Time is a key influence in the policymaking and an invention's level of acceptance (Rijn *et al.*, 2012).

Sweet potato production is a form of organic agriculture, as it requires little or no chemical use.

Diffusion scholars recognize five qualities that determine the success of an innovation (Rogers, 2003; Padel, 2001). They include a) relative advantage**,** b) Compatibility c) Complexity, d) Trialability and e) Observability. Dissemination scholars consider that a populace has five different segments, centered on their tendency to embrace an invention: a) innovators; b) early adopters; c) early majorities; d) late majorities; e) laggards (Alvarez *et al.*, 2013; Perla and Tonetti, 2014).

2.5.1.1 Barriers to Overcome the Opinion of Sweet Potato as a Poor Man's Crop

Sensitization on the health, nutritional and economic benefits of sweet potatoes would help change the attitude of people who perceive it as a poor man's crop. For instance, research done in the United States into the use of sweet potato as a food to be grown in orbiting space stations have been cited (Hill, 1990) as an example of increasing its prestige with the younger age groups. Its high nutritional value has been recognized by its inclusion in school lunch programmes (Harris, 1963; University of New Hampshire, 1979) and in menus for the elderly (Unklesbay, 1978). Investing in farmers through capacity building and technology transference would help change their outlooks (Braun & Duveskog, 2010; Supriadi, Rusastra & Ansari 2012; Waddington & White, 2014).

Involving farmers in adaptation strategies like integrated crop management and decision making would also enable adoption of new technology. Processed sweet potato produces targeted at sophisticated salary individuals and endorsed with trademark would assist address the norm that sweetpotato is not a poor individual's crop. (Wheatley and Loechl, 2008). For instance, the exceptional established market qualities of the orange-fleshed varieties (rich in

beta- carotene and anthocyanin) build novel confidence of breaking the opinion of sweetpotato as a deprived man's food and increasing handling and publicizing of sweetpotato. The status of sweet potato too will improve, if strenuous efforts are made to demonstrate the valuable part it can play in the diet, when it is readily available all year round, reasonably priced, of good quality, of a type adapted to incorporation in local dishes and sold in some tasty (and more prestigious) forms as a nutritious snack or convenience food. Research must also be directed towards the goal of ensuring that the sweet potato remains a food available to the poor.

2.5.2 Decision Making Theory

A choice is a remedy of "whatever has to to be completed" to solve a problem and, as such, is a function of both progressive and normative awareness, the practical affiliations being the judgment regulation and policy. Managing and policymaking are done by, other distinct entities in an organization (Glenn, 1977). The procedures whereby complications are clear and resolved are behavioral. Therefore, understanding management and policymaking elements needs an appreciative of human conduct.

The proficiency of human behaviour depends on its capability to: (1) describe the problematic issue and resolve it; (2) obtaining, collecting, and storing the data; (3) analysis; (4) implement results; and (5) be accountable for choices made and implemented.

2.5.2.1 Government's Role in Decision Making

Most governments do not have clear laws governing sweet potato production and other roots and tuber crops. There is need for farmer's participation in decision-making process. In the recent past new technologies developed without farmers' participation have failed to discourse the problems of rural poverty properly owing towards low levels of adoption (Pretty *et al*., 1985). Furthermore, farmers have their own indicators of performance and quality not well anticipated by researchers' criteria (Jusu, 1999). They are relatively consistent in their selection and their selections correspond with their stated criteria (Aduening *et al*., 2006). For instance Jusu (1999), working on rice noted that low-resource farmers preferred to select from a wide range of varieties rather than just a few high performing ones.

There is need to involve all actors: farmers, institutions, consumers, entrepreneurs (processors) in decision-making as their participation is important in regulating the pricing/

marketing system. Extension- farmer linkages are also important social relations that will determine the rate at which a technology will be adopted. In the recent past, however, the government has laid emphasis on the attainment of nourishment security; and poverty reduction over the development in addition to bulking of value-added varieties of traditional crops for farmers. However, due to a lack of an enabling policy environment to guide planned development of root and tuber crops, their potential in food, feed and industrial applications has not been fully exploited. They have a wide range of uses: food, animal feed and serve as raw materials for industry. Their exploitation for these uses is still low due to lack of focus on their development. In addition, these crops are at various levels of commercialization. Research and development of this crop is advanced and various varieties adapted to the local conditions, with a wide genetic variability in yield, skin and flesh colour, maturity, disease and pest resistance and drought tolerance have been developed and bulking and distribution to farmers is undertaken. Value addition and processing technologies have also been developed but require up-scaling.

2.6 Conceptual Framework

The study used technology adoption and diffusion of innovations theory and concept as most constraints to sweet potato production were linked to the four key components in the dissemination of novel concepts. Sweet potato production technologies used by farmers affected the yield. As indicated by Edmunds *et al* (2003), Nitrogen application time and proportions affect postharvest quality. Good practices prescribe the usage of nitrogen enrichers early and sparingly. Fewer farmers who had infertile lands and grew their sweet potatoes for dual purpose applied fertilizer. The type applied was Diammonium Phosphate applied during planting and Calcium Ammonium Nitrate after the leaves had sprouted to prevent weevil attack increasing yield.

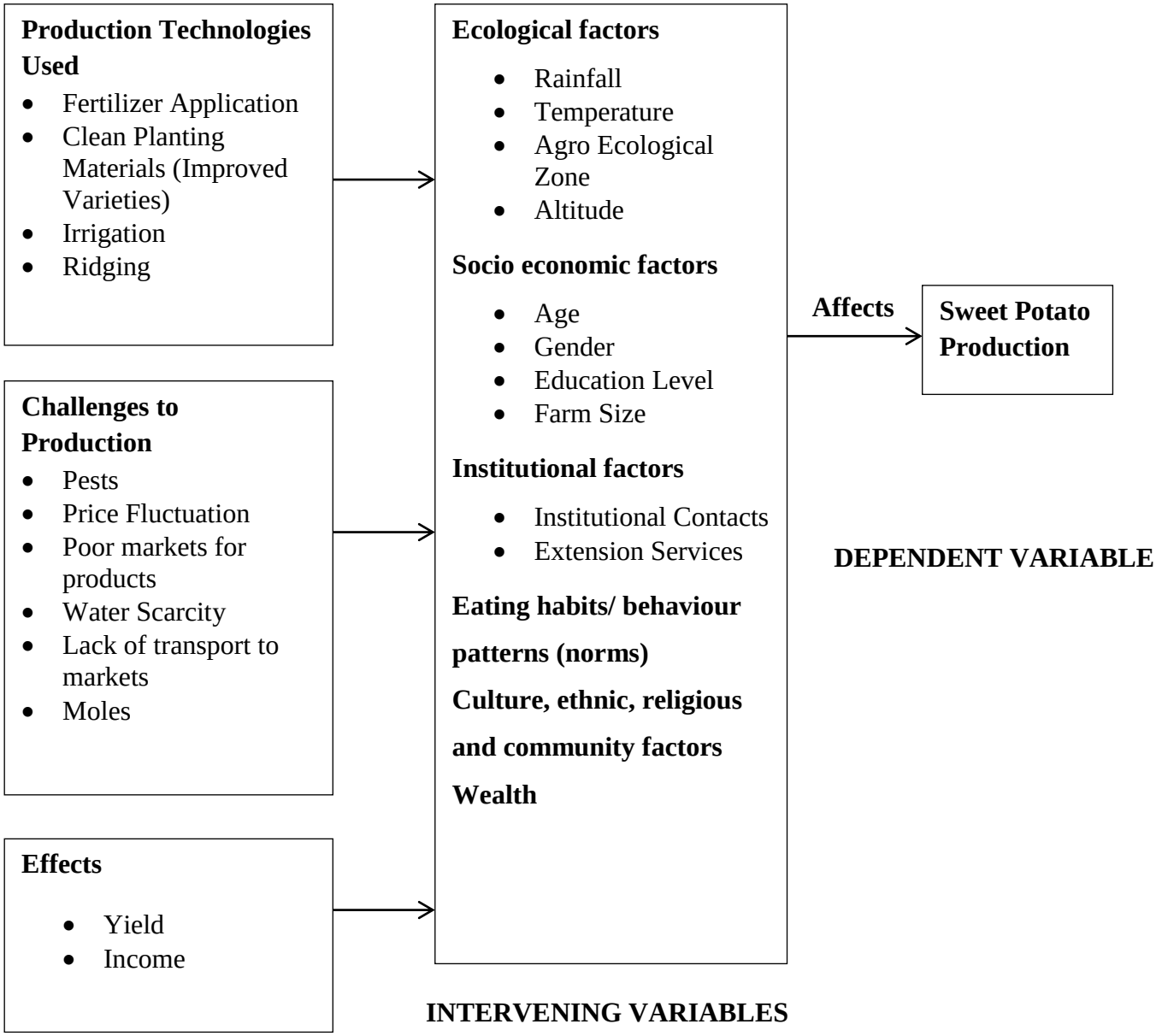
Inadequate access to timely and sufficient quantities of quality clean planting materials of improved varieties due to poor agronomic practices was the major challenge. Majority of the farmers did their own multiplication posing the challenge of identifying quality (disease and pest free) materials, which in turn reduced yield. Farmers who had adopted irrigation grew their sweet potatoes all year round. This technology also suppressed weevil attack increasing yield. Most farmers adopted ridging technology as it formed larger tubers, allowed for tuber expansion and enabled easier harvesting. A number of factors influenced technology use. Socioeconomic factors like the age of the farmers, gender, education and farm size affected

production and the technology used. Majority of the farmers were female. Most were aged between 50-64 years with highest level of education being primary. Majority had small farm sizes and only grew their sweet potatoes for household consumption.

Ecological factors like the agro-ecological zones, which encompass parameters like rainfall, temperature and altitude were highlighted by all farmers as a factor that greatly influenced technology use and production. Institutional factors included institutional contacts and extension services. The contacts included the researchers from KALRO who highlighted scarcity of clean planting material as the major constrain to production and the extension officers from the Ministry of Agriculture who disseminated various modern technologies through training of farmers and setting up of farm field demonstrations. Ethnic, religious, and community factors included farmers of different customs and traditions.

Different farmers used different technologies depending on their farm sizes. Wealthier farmers with large farms used irrigation, obtained quality-planting material from KALRO and had better access to government services. Pests like weevils and moles also led to great losses reducing yield. Lack of an organized marketing system led to price fluctuation, poor markets for products and lack of transport to markets while water scarcity led to weevil attack during the dry season. The farmers who used the modern farm technologies had increased yield. Farmers with larger farm sizes also earned an income from sweet potato production they grew for commercial and subsistence purposes. Yield and income generated from production also determined the rate at which a technology was used. Figure 2.1 shows the conceptual framework.

Figure 2.1: Conceptual Framework



Source: Researcher, 2015

CHAPTER THREE: STUDY AREA

3.1 Introduction

The chapter explains the physical and human characteristics of Manyatta Sub County. It highlights the location, geology, soil characteristics, topography, climate, ecology, drainage and economic activities in the study area, which are illustrated by maps.

3.2 Location and Size of Manyatta Sub- County in Embu County

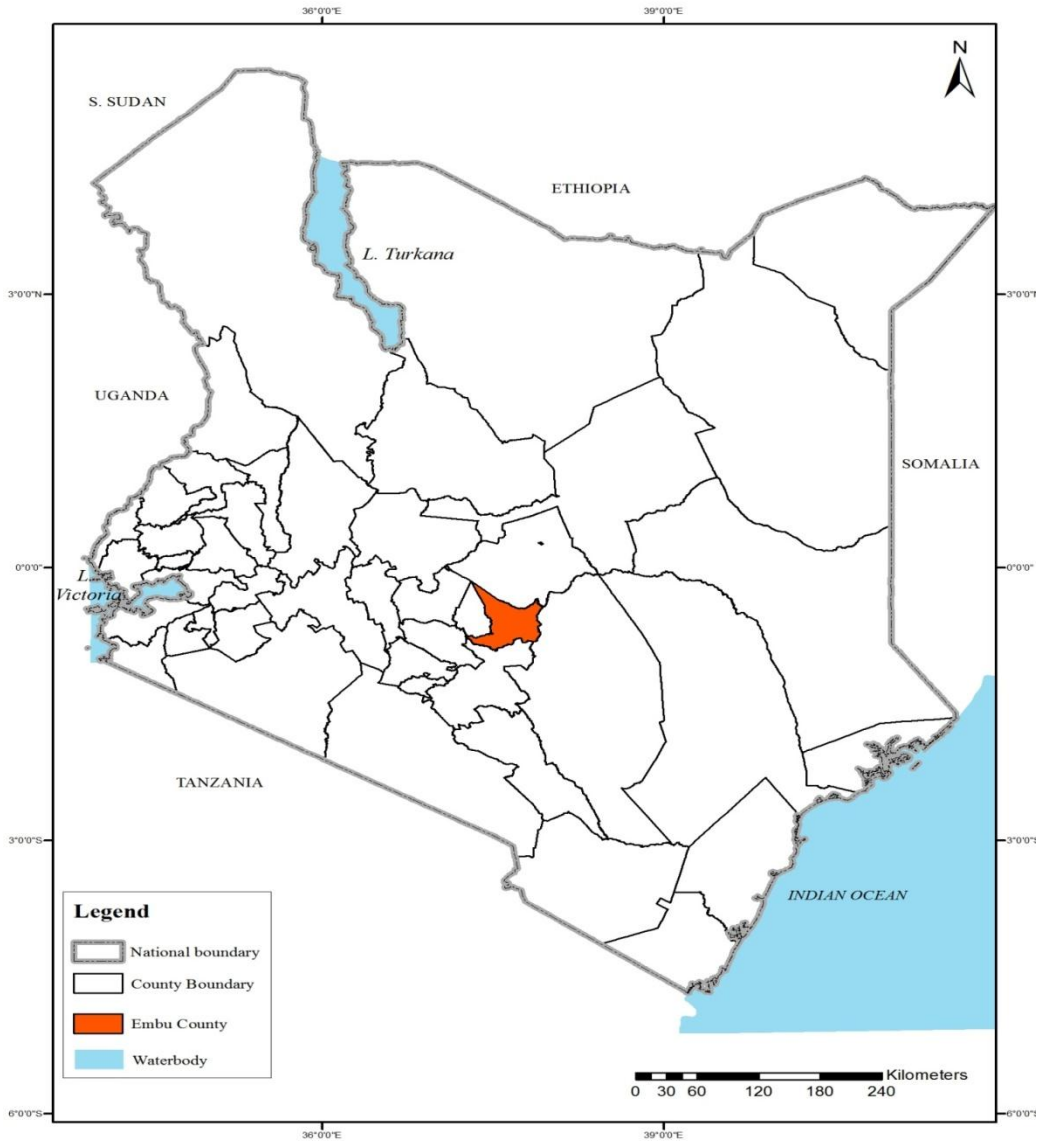
Embu County is situated between latitude 0^{o} 8', 0^{o}50' South, longitude 37^{o}3' and 37^{o}9' East. It borders Kirinyaga County to the West, Kitui County to the East, Machakos County to the South, Murang'a County to the South West, Tharaka Nithi County to the North and Meru to the North West. The county is distributed into four constituencies, namely; Runyenjes, Manyatta, Mbeere South and Mbeere North covering a total area of 2,818 sq. km. Embu County depicts two distinct areas with different agro-climatic and natural characteristics. The upper area around Mount Kenya consists of Runyenjes and Manyatta constituencies, while the lower part consists of Mbeere North and Mbeere South constituencies. The county is traversed by road B6 (Makutano-Meru), which is the major transport spine and passes through major urban centres in the county such as Embu and Runyenjes.

Parts of its borders are defined by permanent rivers such as the Tana, Rupingazi, Kii and Thuci. The county is one of the five whose borders extend to the top of Mount Kenya, the second highest Mountain in Africa at 5199m (Embu County Integrated Development Plan 2013- 2017). The total population of this county as per the 2009 census survey is approximately 516,212 (male 49%, female 51%) with a population density of 200 people per square kilometer with a yearly growing percentage of 1.7%. The number of households is 131,683. It comprises five administrative divisions namely Runyenjes, Nembure, Manyatta, Kyeni and Central with the highest population being at Manyatta. There are 15 locations and 52 sub-locations. The majority of the population (57.3%) is aged between (15-64) years while those aged between (0-14) years account for 37.5% and the rest being over 65 years. Poverty level in Embu stands at 40.8% with dependency ratio being 100:74. The study was conducted in Manyatta Sub County, Embu County. Manyatta constituency has an altitude of 1,000-

1,500 m above sea level and it covers an area of 288.1 km^2 (Embu County Integrated Development Plan 2013- 2017). The specific study areas were Dallas, Kamiu, Njukiri, Nthambo, Kiangima, Itabua, Mbuvore, Manyatta, Gatunduri and Kithimu sub locations located in Central, Nembure and Manyatta divisions. Study area is presented in figures 3.0 and 3.1 respectively.

Fig 3.0: Map of Kenya showing location of Embu County

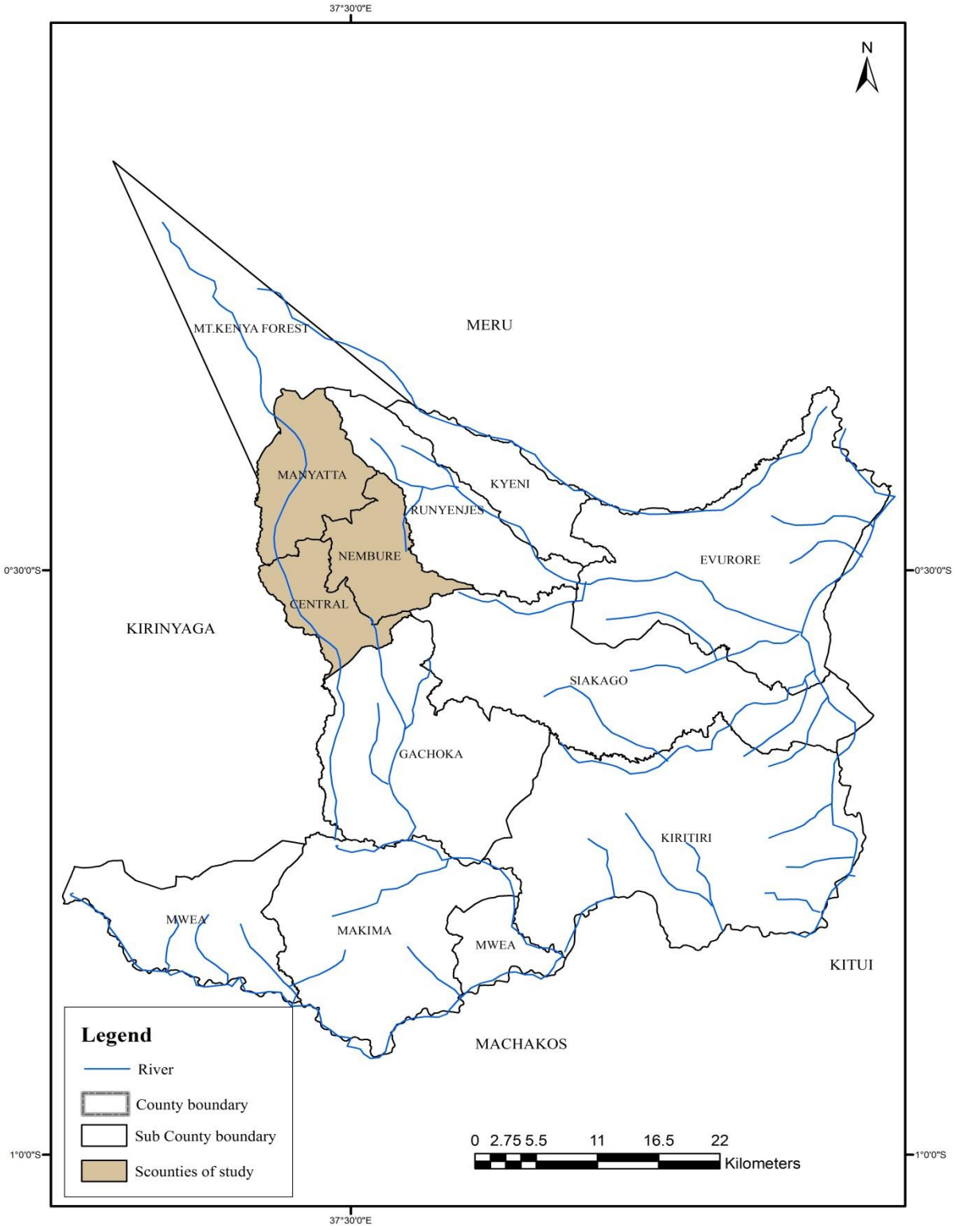
KENYA COUNTY MAP



Source: Survey of Kenya (2011)

Fig 3.1: Map of Embu County showing location of Manyatta Sub County (Manyatta, Central, and Nembure Divisions) and bordering locations

EMBU COUNTY MAP



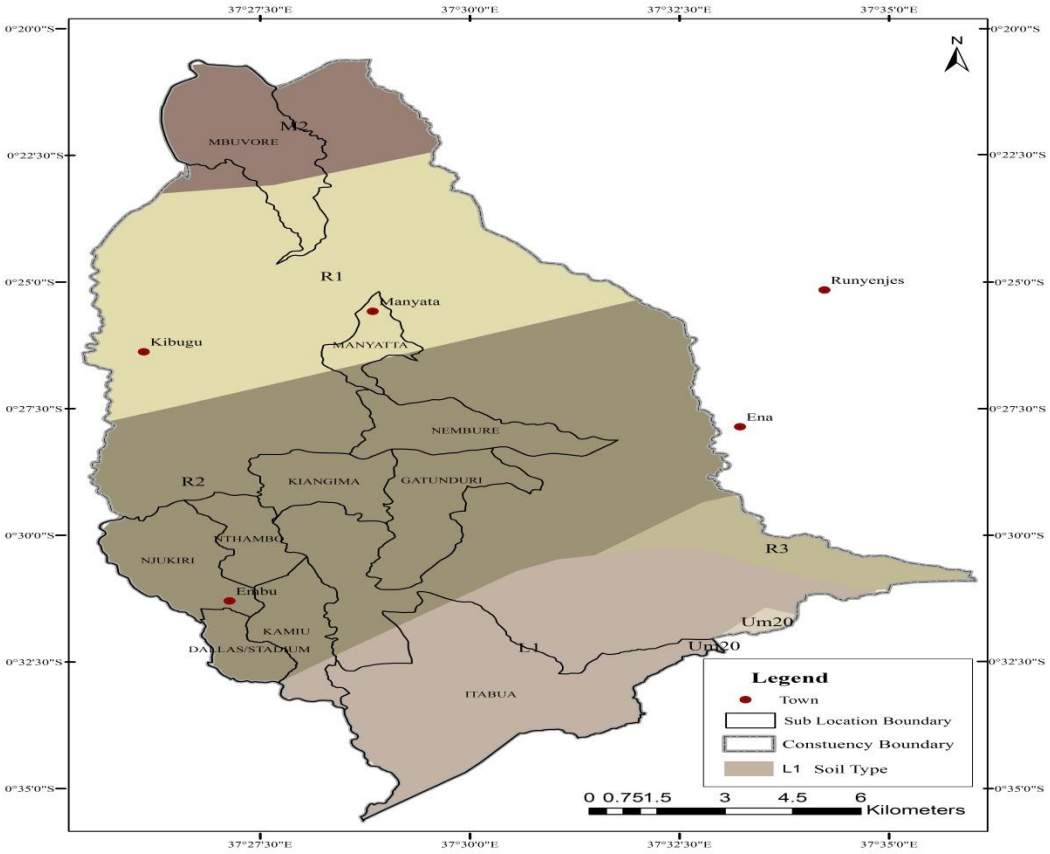
Source: Survey of Kenya (2011)

3.3 Geology and Soils Characteristics

The soil in the study region is volcanic and slightly acidic which makes it suitable for development of cash crops such as tea and coffee. The County has five key soil forms, Nitosols, Andosols, Vertisols, Ferrosols, and Cambisols. The soils and agro ecology of the area are significantly influenced by Mount Kenya and Nyandarua ranges. Manyatta Sub County lodges amongst the main productive lands in the Kenyan highlands, with favorable weather for a variety of agricultural activities. The geology is largely Tertiary Basic Igneous rocks, underlain by well drained, deep to extremely deep, dusky red to reddish brown, clay loam to clay with acid humic topsoils. These soils are mainly classified as Rhodic and Humic Nitisols and Humic Andosols. These soils are suitable for sweet potato production (Embu County Integrated Development Plan 2013- 2017). The soils in the region are shown in figure 3.2.

Fig 3.2: Map showing the soils in Embu County

EMBU SOILS



Source: Survey of Kenya (2011)

3.4 Topography and Climate

Embu County is characterized by highlands and lowlands and slopes from North-West towards East and South-East with a small number of isolated hills such as Kiambere and Kiang'ombe. It rises from about 515m above sea level at the River Tana Basin in the East to 5,199m at the top of Mt. Kenya in the North West. The southern part of the county is covered by Mwea plains, which rise northwards, culminating in hills and valleys to the northern and eastern parts of the county. There are also steep slopes at the foot of Mt. Kenya (Embu County Integrated Development Plan 2013- 2017). Six major rivers serve the county, which are Thuci, Tana, Kii, Rupingazi, Thiba and Ena. Masinga, Kiambere, Kindaruma and Gitaru dams which are situated along the Tana River are found in Embu and produce hydroelectric power for the republic.

The most conspicuous physical features in the county are Mt. Kenya, Kiang'ombe hills, Kiambere hills, Mwea game reserve, River Tana, Masinga dam, Kamburu dam, Kindaruma dam, Kiambere dam and Gitaru dam (Embu County Integrated Development Plan 2013-2017). The County displays a characteristic sequence of belts of vegetation associated with altitude generally found on tropical high mountains. Extending from the high to low altitudes, the belts are: The Nival zone, topped by the mountain peak above 4500m above sea level; The Afro-alpine zone, between 4000m and 4500m above sea level, The moorland zone, between 3300m and 4000m above sea level; The forest zone, between approximately 2000m and 3300m above sea level and containing areas of indigenous forest and areas of forest plantations merging into bamboo zones with increasing altitude; and The agricultural zone below the forest zone (below 2000m above sea level) but in some places extending up to 2800m above sea level 4.3 Km).

The ecological area is categorized as tropical highlands with cool to warm semi-humid to humid climate. Annual rainfall averages 1,500 mm and the precipitation pattern is bimodal. The long rains fall between March and June while short rains come in October to December. Rainfall amount received varies with altitude averaging to about 1,067.5 mm annually and ranging from 640 mm in some areas to as high as 1,495 mm per annum. The temperature ranges minimum of 12 ℃ in July to a maximum of 30℃ in March with a mean of

21℃. The altitudinal range of the county affects temperatures that range from 20^0C to 30^0C. July has an average monthly temperature of 15^0C is the coldest month while September the warmest with an average monthly temperature increasing to 27.1^0C. Localized climate is in certain parts of the county particularly the southern region due to their proximity to the Kiambere, Masinga, Kamburu and Kindaruma dams. The land is mainly arable and is well drenched by a number of rivers and streams. The physical features along with the climatic conditions generate a favorable atmosphere for growing high value crops like coffee, tea and pyrethrum. Additional crops are maize, beans, cereals and horticultural crops such as cabbages, potatoes, avocadoes etc. The low temperatures at the cold season can be attributed to the geographical location of Embu County at the south eastern slope of Mount Kenya and also due to its elevation from the sea level which stands at 1350 meters or 4429 ft (Embu County Integrated Development Plan 2013- 2017).

3.5 Ecological Conditions and Drainage

Embu County displays the characteristic agro-ecological outline of the windward side of Mt. Kenya, from cold and wet upper zones to hot and dry lower zones in the Tana River Basin. The average yearly precipitation reflects this disparity: from more than 2200 mm at 2500 m to less than 600 mm near the Tana River at 700 m. The variation is mainly due to the mountain but also to the "water recycling" effect of the forest by evapo-transpiration. Above 2500 m, rainfall decreases due to the lower moisture content of the colder air and the stronger influence of the trade wind system, but nevertheless the area is still very wet (Embu County Integrated Development Plan 2013- 2017). Embu County has different agro ecological zones ranging from Upper Highlands (UH), Upper Midlands (UM), Lower Highlands (LH), Lower Midlands (LM) to Inlands Lowlands (IL).

Manyatta Sub County, which was the specific area of study, is located between UM1 to UM4. Manyatta Sub County has a diversity of agro ecological environments ranging from high altitude dairy or temperate vegetables zone (UM1) to very dry lowland livestock-millet zone (LM5). Ten key agro ecological zones cover 81% of agricultural land in the County (UM1-UM5 and LM3-LM6). Highlands (higher than 1,500m above sea level) and midlands (1,200m to 1,500m above sea level) and other topographical features like hills and valleys typical of Kenya's Eastern Highlands characterize the landscape of the County. Highlands cover parts of Manyatta Division and midlands dominate most areas of Embu Municipality

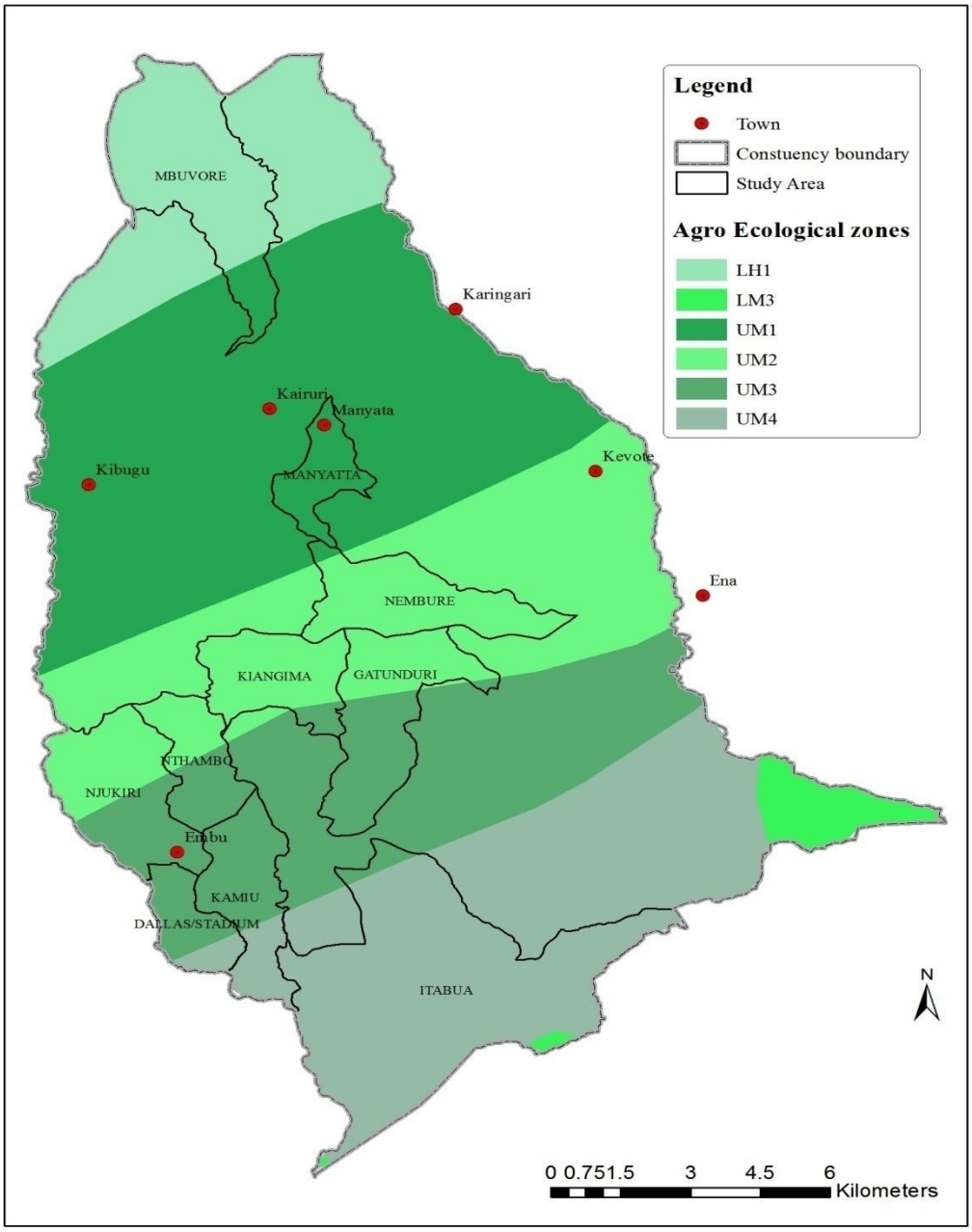
(Central Division) and part of Nembure Division (Embu County Integrated Development Plan 2013- 2017). Four major rivers, namely Rupingazi, Thuci, Kii and Ena, all following a southeast direction, drain the County. The agro ecological zones are presented in figure 3.3 and Table 3.0.

Table 3.0: Agro Ecological Zones.

Agro ecological Zone	**Altitude metres above sea level**	**Annual Mean Temperature (C)**	**Annual Average Rainfall (mm)**	**Land Use potential**
UM 1	1520-1800	19.2- 17.6	1500-2400	Coffee/tea zone
UM 2	1280-1680	20.6-18.2	1500-2400	Coffee zone
UM 3	1280-1520	20.6-19.2	1400-2200	Marginal coffee zone
UM 4	1520-1770	19.3-18.0	750-1600	Sunflower/ maize zone
LH 1	1830-2200	17.4 - 14.9	1700-2600	Tea- dairy zone

Source: NEMA, 2009

Figure 3.3: Map showing Agro ecological Zones in Embu County



Source: Survey of Kenya (2011)

3.6 Human Activities

Manyatta is a richly endowed sub county with a lot of resources such as arable land for cultivation, water, pasture for livestock, forests, hills with fascinating natural scenery and wildlife. This is what drives the economy of Embu County with a big chunk attributed to Agriculture, which accounts for about 70% of income (Embu County Integrated Development Plan 2013- 2017). The cash crops grown include tea and coffee due to the high precipitation and temperatures experienced in the area selected farmers also plant Macadamia.

Tourism sector is rapidly growing with the proposed new route to be opened that allows access to Mount Kenya by mountain climbers. It also has natural resources as wildlife, livestock, arable land, water, pasture, forests, hills, and tourist attractions as waterfalls, Kimiriri and Karue Hills. The key economic activities in the area are Tea, Coffee, Macadamia and dairy farming in the upper zones (Manyatta and Runyenjes) and livestock and bee keeping in the lower zones (Mbeere and Mwea). Road Network has Bitumen Surface of (120 Km), Gravel Surface of (402 Km), and Earth Surface (914.3 Km).

CHAPTER FOUR: RESEARCH METHODOLOGY

4.1 Introduction

This section covers the study design, sources of data, sampling techniques, sample size and data analysis. Given the main aim of the research, which is to determine the effects of farm technologies on sweet potato production in Manyatta Sub County, Embu County, a case study was the most appropriate study design to use for this research.

4.2 Study Design

The study used a case study design. This excels at giving an understanding of a complex issue and can spread knowledge or enhance strength to what is recognized through preceding investigation. They highlight comprehensive background examination of a restricted number of events and their associations. It provides in-depth understanding of problem under investigation.

4.3 Types and Sources of Data

Primary and secondary data were used. Primary data was acquired from household questionnaires, key informants interviews, observation, and photographs. Key informants interviews were directed to the "Ministry of Agriculture and Kenya Agricultural and Livestock Research Organisation extension officers". Key informants interviews were conducted to give an in-depth understanding of the information received from the farmer households interviews. The interviews helped provide information that was used in the analysis of effect of farm technologies on sweet potato production. Questionnaires were used to obtain information from sweet potato growing farmers on effects of these technologies on sweet potato production, the income generated from the production, the level of adoption and challenges to production. Observations of sweet potato varieties grown in farms backed up the information received from the interviews. This was then recorded through photographs.

Secondary data was obtained from publications from scholarly journals which are found in Libraries (Africana). Data was also collected from theses and dissertations, government documents which included policy papers and research reports owned by governments, some

of which are sponsored by international agencies. In Kenya, example is National Agricultural Research System Policy, from reviewing of relevant books, abstracts which gave a list of journal articles with summaries and grey literature. More data was sourced from KALRO-Embu Library and the Ministry of Agriculture in Embu. The nature of data collected was on the various farm technologies currently being used for sweet potato production.

4.4 Target Population

The study area had a population of 154,632 people (76,073 males, and 78,559 females) and 42,717 households in the 2009 population census (KNBS, 2009). The number of sweet potato growing farmers was 973 i.e. 800 farmers from Central and Manyatta divisions while 173 from Nembure division (Ministry of Agriculture, 2009). The study used sweet potato farmers' population as target population. It focussed on female farmers because they had knowledge on sweet potato production, as this is mostly a female grown crop.

4.5 Sample Size and Sampling Techniques

4.5.1 Sample Size

A sample size of 381 farmers was arrived at for only sweet potato farmers in Manyatta Sub County according to Fisher's formula for sample size determination (Fisher's *et al.*, 1991; Edriss, 2003) i.e.

$$\mathbf{n= z^2 (pq) /d^2}$$

Where,

n= sample size of sweet potato farmers

z= Confidence/significance level – 95% for a two tailed test at the 0.05 significance level which is approximately 1.96

p= Population proportion of sweet potato farmers (p=0.45) an approximation of 45%

q= (1-p)

d= degree of accuracy/standard margin error (0.05)

$n=1.96^2*(0.45*1-0.45)/0.05^2$

n= 380.3184

n= 381 sweet potato growing farmers.

The target population was 973 sweet potato growing farmers while the sample size was 381.

4.5.2 Sampling Techniques

Manyatta Sub County is diverse and due to limited time and finances, the study could not cover the entire sub county. It only covered farmers from 10 sub locations that mainly grow sweet potatoes i.e. Dallas, Kamiu, Njukiri, Nthambo, Kiangima, Itabua, Mbuvore, Manyatta, Gatunduri and Kithimu sub locations, were the study areas. Purposive random sampling techniques were used to select only sweet potato growing farmers. The sampling unit was female in sweet potato growing households. Out of 973 sweet potato farmers (800 from Central and Manyatta Divisions and 173 from Nembure division), 381 farmers were randomly selected to provide the required sample size. Extension officers from the Ministry of Agriculture helped identify the number of sweet potato farmers through selection from a random list.

The sample was proportionately distributed with Central and Manyatta divisions having the largest population of sweet potato farmers thus had a bigger distribution.

Central and Manyatta divisions where Dallas, Kamiu, Njukiri, Nthambo, Kiangima, Itabua, Mbuvore, Manyatta, Gatunduri sub locations are located had 82.2% of the farmers interviewed while Nembure division where Kithimu sub location is had 17.8% farmers. Sample distribution where Dallas, Kamiu, Nthambo, Kiangima, Itabua, Mbuvore, Manyatta and Gatunduri sub locations were 9.1% each and 9.4% from Njukiri forming (82.2%) while Nembure sub location (17.8%). Identification of farmers, who had accepted and not accepted the technologies, was undertaken with the help of the "Ministry of Agriculture" and KALRO extension officers employed in the area.

4.5.3 Response Rate

Out of 381 respondents selected for the interview, only 339 were able to provide answers to all questions, 42 did not respond thus 100% response was not achieved. A response rate of

(88.9%) was attained while 11.1% did not respond and according to Mugenda and Mugenda (1999), a response rate of 70% and over is good for an analysis. It therefore goes that the study registered a good response rate. Out of 339 farmers, 220 were female while 119 were male.

4.6 Data Collection Instruments

4.6.1 Questionnaires

The study used semi-structured questionnaires that were administered by the researcher to collect both quantitative and qualitative data from the farmers' households. 381 questionnaires were administered to only sweet potato farmers. Questionnaires were based on objectives of the study providing information on household sweet potato production, income generated from its production, the level of adoption of the various production technologies and challenges to production. This information aided in assessing the effects of technologies on household sweet potato production of the study area. The semi-structured questionnaire allowed respondents to give their own view regarding issues under study.

4.6.2 Interviews

Key informants interviews were used in the study. They were used to gather information from governmental and nongovernmental organisations. Government interview (Kenya Agricultural and Livestock Research Organisation and Ministry of Agriculture), provided information on sweet potato technologies adopted in the area, their effects on production and the household and economic benefits in the study area. They were also interviewed on the new sweet potato production technologies they had introduced to the farmers and their significance in increasing yield. These interviews provided in-depth understanding on effects of farm technologies on sweet potato production in Embu County. These interviews were also carried out to support farmers' household findings.

4.6.3 Observation, Recording of Notes and Photography

This involved, recording of farming activities with particular interest on, sweet potato production technologies within the study area. Observation focused on available varieties of sweet potatoes planted in the farms, acreage under sweet potatoes, and the yield. The information collected using this method included sites where the farmers grew sweet potatoes.

4.7 Data Analysis

Collected data was numerical and qualitative in nature. Data obtained from the field was entered in SPSS (Statistical Package for Social Science) to analyze the raw statistics and Excel sheet, and simple correlation was the statistical method of analysis applied to test the hypothesis and meet each objective. To find the production technologies used and challenges to production frequency tables were generated. To assess the effects of sweet potato production to farmer households, the study assumed that the effects of farm technologies on sweet potato production could be evaluated by, relating production and technological effects (by relating technologies used, the level of adoption, challenges and the economic benefits from sweet potato production). Technological effects were measured in terms of yield per variety and the income generated from each production.

Simple Correlation tested the hypothesis that stated, 'there is no relationship between the technology applied and the sweet potato yield in Manyatta Sub County'. Simple linear correlation measures the relationship between two variables. The correlation coefficient value varies between +1 and -1. When the value lies around ± 1, then it is said to be a perfect degree of association between the two variables. As the correlation coefficient value goes towards 0, the relationship between the two variables becomes weaker. The parameter being measured is (rho) and is estimated by the statistic r, the correlation coefficient. All correlation was calculated at a significance level of 0.05.

A table of technologies applied and their effects on sweet potato yield was then generated using a cross tabulation analysis and the results subjected to simple correlation analysis tested the hypothesis that stated 'there is no relationship between the technology applied and the sweet potato yield'. The test showed that there was an association between the two variables and also gave the strength of the relationship.

4.8 Limitations of the Study

The scholar met fairly a number of challenges linked to the investigation when collecting data. The investigation was carried under financial constraint because of limited resources. The data was therefore collected from 10 sub-locations that mainly grew sweet potatoes. Some respondents were unable to respond to some of the questions. The researcher overcame

this by supplementing the information given by farmers by interviewing key informants representatives from the "Kenya Agricultural and Livestock Research Organisation (KALRO)" and Ministry of Agriculture (MoA).

4.9 Ethical Issues

Approval to carry out the study was acquired from the University. Confidentiality issues- The information shared by the participants was treated with utmost confidentiality. The investigator was also sensitive to the age, gender, culture, religion, and social class of the participants. Each contributor was informed of the purpose of the examination at the start of every discussion. Location of participation was communicated to the contributors prior to the scheduled interview date. In case of any risks associated with the research, the participant was notified. This study did not pose any risk factors to the farmers. Most of the data was from the farming activities. The participants were selected on a voluntary basis.

CHAPTER FIVE: RESULTS AND DISCUSSIONS

5.1 INTRODUCTION

This section presents the results and discusses the findings of the study. The results are organized according to objectives.

5.2 CHARACTERISTICS OF THE RESPONDENTS

Farmers interviewed 339 while the key informants interviewed were 5 members from the NGO (African Christian Church and School), 3 research scientists from the Kenya Agricultural and Livestock Research Organisation and 5 extension officers from the Ministry of Agriculture.

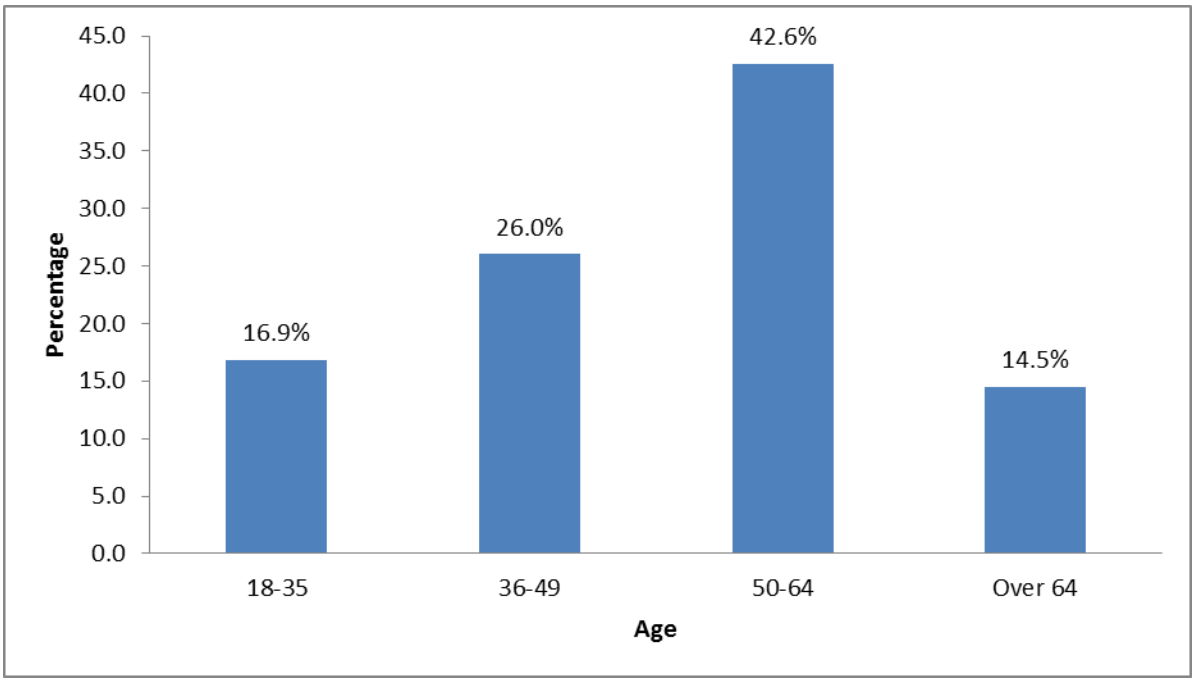
5.2.1 Gender Distribution

The study revealed that, gender of farmers mainly involved in sweet potato production was female which stands at (65%) while (35%) was male. This confirms that the crop is largely grown by women at household level mainly for family consumption thus providing a source of food security and a supplementary household income. Gender was important in this study as most women play a crucial role in rural economy through agricultural activities.

5.2.2 Age of the Respondents

Based on the study results, majority of the sweet potato growing farmers (42.6%) were aged between 50-64 years, 26% were 36-49 years, 16.9% were between 18-35 years while 14.5% were over 64 years (Figure 5.1). Most sweet potato farmers were aged between 50-64 years and above and retired thus had vast experience on production technologies and had adopted ridging and the use of certified vines, which increased their yield.

Figure 5.1: Age Groups of Sweet Potato Growing Farmers

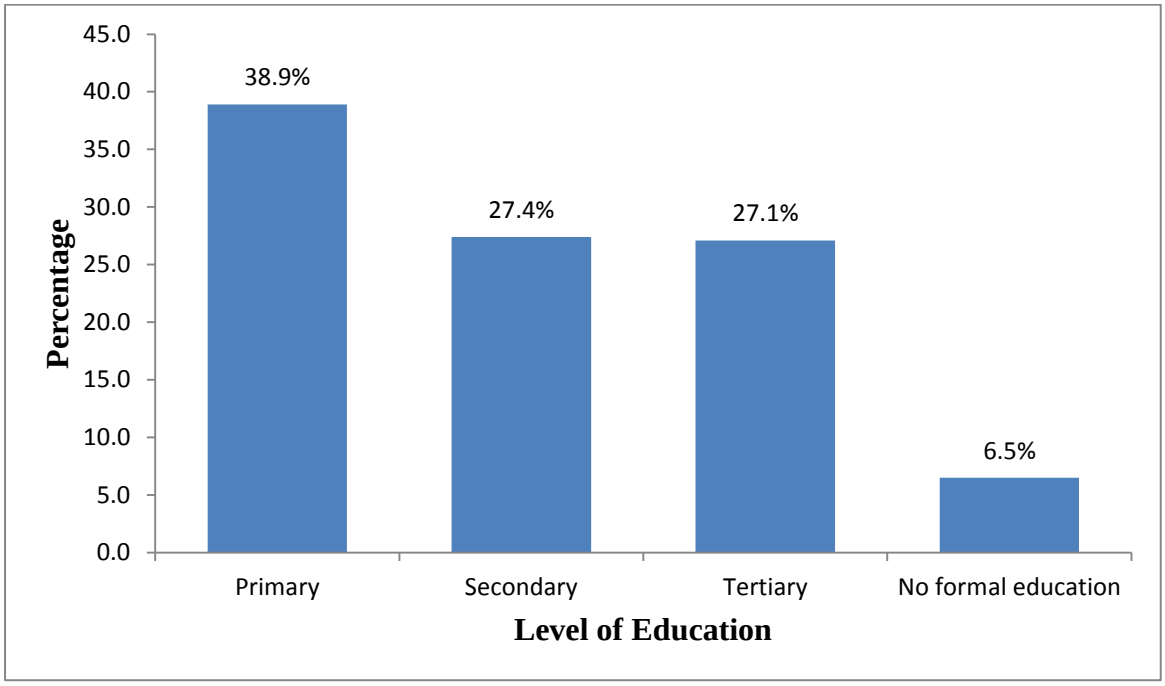


Source: Researcher, 2015

5.2.3 Level of Education

The study revealed that the majority of the sweet potato farmers had primary education (38.9%), followed by secondary education (27.4%), tertiary level of education (27.1%) and no formal education (6.5%) (Figure 5.2). Education played a critical role in sweet potato production as it determined the level of technology adoption and use. Most farmers were not well informed with up- to- date information on new farming techniques and technologies, which would enable them grow sweet potatoes efficiently and economically. Empowering farmers increases local food availability, which addresses hunger issues, and sustainable agriculture, which encompasses adoption of sustainable agricultural practices. These practices guarantee food security in future by preserving and rehabilitating food production resources like soil and water. Sweet potato is one such crop that requires less labour, input to produce maximum yield, and thus acts as a food security crop in many regions of Kenya and Africa (Stathers, 2005).

Figure 5.2: Level of Education

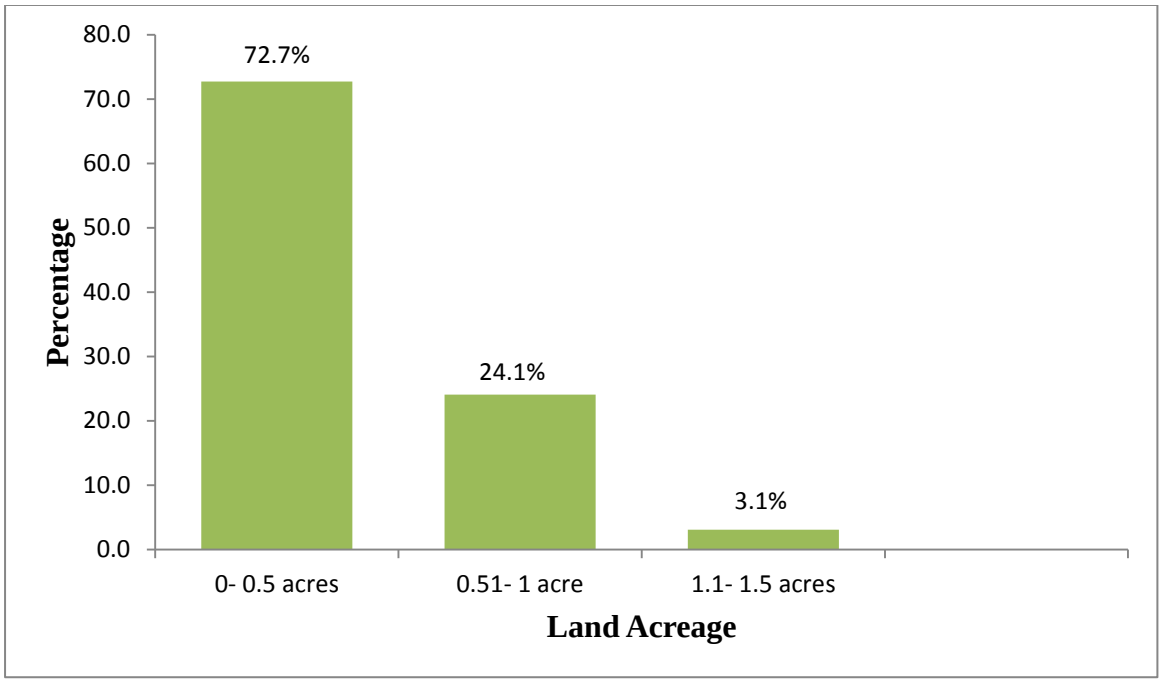


Source: Researcher, 2015

5.2.4: Farm Size

Majority of the respondents indicated 0-0.5 acres as their land acreage under sweet potato production (72.7%), followed by 0.51- 1 acres (24.1%) and 1.1- 1.5 acres (3.1%) respectively (Figure 5.3). Farm size affects production and technologies adopted were used to find out the adoption levels of these technologies and to assess the impact levels of these technologies to households. It influenced the technology used by a farmer. Most farmers in the study area grew sweet potato in small acreage of land (0-0.5 acre) for household consumption by intercropping with other crops like beans and maize while those growing on larger acreage (0.51-1 acres and 1.1-1.5 acres) grew for both household and commercial purposes thus had adopted irrigation technology which enabled them to plant all year round.

Fig 5.3: Land Area under Sweet Potato Production.



Source: Researcher, 2015

5.2.5 Agro-ecological Zones

All the farmers interviewed indicated that the agro ecological zones and climate affected sweet potato production. The agro ecological zones and climate influenced production technologies used by farmers, which in turn affected sweet potato production, thus was used to find out the adoption levels of these technologies. Most sweet potato producers interviewed lied between UM1, UM2, UM3, UM4 and LH1 respectively. Manyatta sub location is situated in UM1. Most sweet potato farmers who had adopted irrigation grew them on large scale for commercial purposes at UM2, where Njukiri, Nthambo, Kiangima, Gatunduri, and Nembure (Kithimu) sub locations are located. The temperature in this zone is lower compared to UM3 where Kamiu and Dallas sub locations are situated. Itabua sub location is in UM4 while Mbuvore sub location is in LH1.

5.3 SWEET POTATO PRODUCTION TECHNOLOGIES

This section addresses objective one of the study. It shows the different sweet potato production technologies adopted by farmers in different households.

5.3.1: Fertilizer Application

From the study, most of the respondents (88.2%) indicated that they did not use fertilizers and only 11.8% used it for sweet potato production. Majority of the farmers did not apply fertilizer because they perceived their soils to be highly fertile. The soil is volcanic and slightly acidic making it suitable for sweet potato production. The crop therefore grows best in light textured soil with the optimal pH of 5.5-6.5. Farmers who applied fertilizer mainly grew their sweet potato as a fodder crop while others used it on infertile soils. Key informants interviews also confirmed that manure or fertilizer application on already fertile soils resulted to high level of fertility, which in turn can result in excessive vegetative growth at the expense of tuber and starch formation or oversized and irregularly shaped roots. Sweet potato has high nutrient requirement and rapidly exhausts the soil unless provision is made for the replacement of the nutrients removed. It is important to replenish potassium and phosphorus regularly.

The results of this study thus compare with previous research done by the International Potato Centre in Lima, Peru (2009). This study recommended the use of fertilizer on infertile soils during sweet potato production. Farmers (11.8%) used both organic manure and inorganic fertilizer (Diammonium Phosphate DAP) before planting and Calcium Ammonium Nitrate (CAN), which was applied in small quantities after the leaves had sprouted to control infestation by the sweet potato weevils. DAP was mixed with farmyard manure before planting and CAN was used as a top dresser after the leaves had sprouted. Key informant interviews from the Ministry of Agriculture, "Kenya Agricultural and Livestock Research Organisation" and non-governmental organisations recommended the use of farmyard manure (organic) as the best to apply, and is the most effective while the use of inorganic fertilizer has its disadvantages in that it is not easy to control the power of hydrogen (pH).

A mixture of both organic manure and inorganic fertilizers balances both the microbes in the soil and the pH. However, the use of CAN as a nitrogen fertilizer helps increase yield because it is high in lime content thus improves soil fertility. Previous studies highlight organic and inorganic fertilizer use as a production technology in sweet potato production (Scott *et al.*, 2000; Edmunds, 2003; Mbanaso *et al.*, 2012). A similar study by Ezeano (2010) identified animal and mineral fertilizer as the technologies that were highly accepted by farmers in sweet potato production in Southeastern Nigeria. Excessive application of fertilizer reduced palatability of the tubers. Some farmers also soaked their vines with pesticides for 20 minutes

before planting to prevent weevil attack. The amount applied was 16kg/acre with a ratio of 23:23:0. CAN was the most effective fertilizer as it controlled weevil attack, increased yield and enhanced the formation of larger tubers.

5.3.2 Types of Improved Sweet Potato Varieties

Majority of the respondents (30.9%) indicated that Bungoma was the variety of sweet potato they grew in their farms. This is because the planting material was readily available and cheaper compared to the other varieties. Most farmers reported that Bungoma produced larger tubers with red skin and yellow flesh. Kenspot 2, 3, 4 followed with 26.6%, Tainung that is a variety of the Orange fleshed sweet potato was at 14.2%, SPK 004 (orange fleshed type) at 12.7%, Kemb10 at 10.6% while the least planted varieties i.e. KSP 20, Kemb 36 also locally known as *Muibai* and Kemb 23 (*Gikanda)* shared the remaining 5.0% (Table 5.1). Tainung and SPK 004 are orange fleshed thus are rich in Vitamin A (beta-carotene) which is essential for growth in children and is also important in building the body immune system against diseases and blindness.

Kenspot was the most important variety in terms of accessibility (26.6%). Kenspot 2, 3 and 4 are also bought by most consumers. Kenspot 2 has red skin and white flesh while Kenspot 3 and 4 are orange fleshed with red skin (Plates 3, 4, 5). Kemb 10 is an improved variety that was cloned from the original variety called Ex- Rwambiti. It has white skin and cream flesh. It is more drought tolerant than other varieties thus does very well in marginal areas. It is very tasty and thus highly consumed (Plate 2). A similar research conducted in Mozambique on the introduction of the Orange fleshed sweet potato varieties increased Vitamin A consumption and Serum Retinol concentrations in infants (Low *et al.*, 2007). SPK 004 is fast growing but not palatable (Plate 8). KSP 20 (*Wanjugu*) adapts well in low altitude temperatures and in the study, most farmers who grew it were located in UM3 and UM4 agro ecological zones, which have higher temperatures compared to UM1 and UM2.

Kemb 36 and Kemb 23 are local varieties that are dual purpose i.e. they are grown as food and fodder for domestic animals. KSP 20, Kemb 10 and SPK 004 performed well in wetter areas of zone (UM3, UM4 and irrigated areas of UM2 like Njukiri, Nthambo and Kithimu sub locations). The type of varieties planted and the accessibility greatly affected sweet potato production (yield). Bungoma variety was not native to the study area but was easy to source for compared to the other varieties, which are native to Manyatta and are high yielding compared to Bungoma variety (Plate 1). Similar research work done in Bungoma County of

Western Kenya on Bungoma variety found out that, it has lower weevil damage and thus has a high vine yield (Wamalwa & Grant, 2013). This therefore confirms why farmers largely prefer to grow it. SPK 004 variety is an old variety compared to the other varieties and is low yielding and less palatable (not tasty). Farmers who plant the Kenspot 2, 3, 4 and Kemb 10 varieties grow them under irrigation in Njukiri, Nthambo, Kamiu and Nembure sub locations. Kenspot varieties have better average root yield, moderate field resistance to pests and diseases and moderate dry matter content thus readily acceptable by consumers.

Table 5.1: Improved Sweet Potato Varieties

Sweet Potato Variety	**Frequency**	**Percentage (%)**
SPK004	43	12.7
Bungoma	105	30.9
Kenspot 2,3,4	90	26.6
Kemb 10	36	10.6
Tainung	48	14.2
KSP20, Kemb36, Kemb23	17	5.0
Total	**339**	**100**

Source: Researcher, 2015

Plate 1: Bungoma Variety

Source: Researcher, 2015

Plate 2: Kemb 10 Variety

Source: Researcher, 2015

5.3.2.1 Sweet Potato Variety Preferred By Farmers

Majority of the farmers indicated that they preferred Kenspot 2, 3 and 4 varieties, which stood at 36.3%. Kemb 10 was the second most preferred variety at 23.6%, followed by Bungoma at 19.2%, Tainung, SPK 004 was at 16.5%, and the least was Kemb 23, Kemb 36 and KSP 20 at 4.4% (Table 5.2). Kenspot 2, 3 and 4 are preferred because they produce larger tubers and are early maturing (Plate 3, 4 and 5). It is also high yielding and highly consumed (marketable) due to the purple skin colour. This variety also has broad leaves which spread thus prevents the soil from drying up during the hot seasons. This helps the soil maintain moisture and prevent the cracking of soil thus suppressing weevil attack. Kemb 10 is also highly marketable because of the yellow hard flesh and adapts better in low altitude areas.

When the Kenspot varieties with broader leaves are intercropped with the Kemb 10 variety which has narrow leaves, they help cover up the soil preventing it from cracking (Table 5.2). Although most farmers preferred the Kenspot varieties, the planting material was scarce making the vines expensive for the peasant farmers, which affected the yield as most opted for cheaper and low yielding varieties. These Kenspot varieties also produced larger, tastier tubers and was high yielding compared to Bungoma variety thus were greatly preferred by most farmers. Similar studies conducted on sweet potato varieties for farmer preference highlighted that sweet potato yield in Eastern and Central Kenya were low due to the use of low yielding varieties and poor agronomic practices (Ngoroi *et al.*, 2013). Other research work done on improved varieties was done in Lima Peru and this study highlighted that, the Kenspot varieties have great benefits to the body when consumed. Their purple skin contains anthocyanin, which helps prevent colon cancer (CIP, 2009, Obonyo, 2004).

Table 5.2: Variety Preferred By Farmers

Sweet potato	**Frequency**	**Percentage (%)**
Kemb 23, Kemb 36, KSP 20	15	4.4
Kenspot 2, 3 and 4	123	36.3
Bungoma tasty	65	19.2
Kemb 10	80	23.6
Tainung, SPK 004	56	16.5
Total	**339**	**100**

Source: Researcher, 2015

Plate 3: Kenspot 2 Variety

Source: Researcher, 2015

Plate 4: Kenspot 3 Variety

Source: Researcher, 2015

Plate 5: Kenspot 4 Variety

Source: Researcher, 2015

Plate 6: Kemb 10 Variety on Harvesting

Source: Researcher, 2015

Plate 7: Kenspot Variety on Harvesting

Source: Researcher, 2015

Plate 8: SPK 004 Variety

Source: Researcher, 2015

5.3.2.2 Variety Maturity

Most of the respondents indicated that Kenspot 2, 3 and 4 had a shorter maturation period of between 3-4 months (48.1%). Kemb 10 also had a maturity period of $3^{1}/_{2}$-4 months was at 30.4%, Bungoma matures between 4-5 months was at 16.2% and Kemb 23 and Kemb 36 matured between 5-6 months was at 5.3% (Table 5.3). Farmers who planted Kenspot varieties and Kemb 10 all year round (those who irrigated) had higher yield.

Table 5.3: Variety Maturity

Sweet potato	Maturity	Frequency	Percentage (%)
Kemb 10	$3^{1}/_{2}$- 4 months	103	30.4
Kenspot 2,3,4	3- 4 months	163	48.1
Bungoma	4 - 5months	55	16.2
Kemb 23, Kemb36	5 - 6 months.	18	5.3
Total		**339**	**100**

Source: Researcher, 2015

5.3.2.3 Pests and Diseases Observed in the Farms.

The study observed that 41.0% of the farmers experienced moles as the most important pests on their farms. The sweet potato weevil followed at 25.4%, squirrels attacks was at 17.4%. Farmers who never observed any pests or diseases in their farms were at 13.6%. Sweet potato

virus and Alternaria disease was the least observed at 2.6% (Table 5.4). Pests and diseases attacks adversely affect sweet potato yield leading to major losses and food insecurity. Moles destroyed tubers by exposing the soil leading to wastage and tuber rooting predisposing them to weevil attack. The sweet potato weevil caused severe damage to the tubers causing many farmers to abandon sweet potato production, and ventured into French beans farming. Squirrels attacks were mostly observed in the warmer zones.

Farmers who never observed any pests or diseases in their farms attested this to the adoption of proper agronomic/cultural practices within their farms. These included selection and planting of clean, certified planting materials and the use of modern technologies like irrigation that controlled weevil attack. Key informants interviews confirmed that these technologies increased the yield per variety. Sweet potato virus and Alternaria disease was the least observed at 2.6% (Table 5.4). When planting, most farmers dip the planting material in Diaznon pesticide to prevent pest attack like weevils thus increasing yield (GoK, 2007). Wambugu (2003) in a research on pests and diseases affecting sweet potatoes in Kenya found that sweet potato feathery mottle virus (SPFMV) disease reduces yield by up to 80%.

Table 5.4: Pests and Diseases.

Sweet potato diseases and pests	**Frequency**	**Percentage (%)**
Sweet potato virus/ Alternaria disease	9	2.6
Sweet Potato Weevils	86	25.4
Squirrels	59	17.4
Moles	139	41.0
None	46	13.6
Total	**339**	**100**

Source: Researcher, 2015

Plate 9: Kenspot 4 Attacked by Weevils

Plate 10: Bungoma Attacked by Weevils

Source: Researcher, 2015 **Source: Researcher, 2015**

5.3.2.4 Varieties Susceptible to Pests and Diseases.

The study shows that 15.9% of the farmers never experienced any pests or diseases in their farms. Kemb 10 and Bungoma were resistant to pest attack with 6.2% and 10.9% respectively. Kenspot and Kemb 10 were also tolerant to pest attack (16.2% and 12.4% respectively). The local varieties (Kemb 23, Kemb 36), Tainung and SPK 004 were adversely attacked by pests at 20.1%, 7.4% and 10.9% respectively (Table 5.5). Susceptibility, tolerance and resistance depend on agronomic aspects and selection of materials for planting. As indicated in Table 5.6, (15.9%) never experienced pests and diseases due to proper agronomics practices, which involved sorting for certified planting material from the Kenya Agricultural and Livestock Research Organisation, and adopted irrigation as a modern technology known to suppress weevils attack. Wambugu (2003) carried a similar research on improvement and transmission of genetically altered virus resilient sweet potatoes and concluded that the adoption of proper agronomic practices would improve sweet potato yield.

Table 5.5: Varieties Susceptibility to Pests and Diseases.

Susceptibility	**Frequency**	**Percentage (%)**
Very Susceptible		
Tainung (Orange Fleshed)- Vit A	25	7.4
All, Kemb 23, Kemb 36 (Local Varieties)	68	20.1
SPK 004	37	10.9
Tolerant		
Kemb 10	42	12.4
Kenspot 2	55	16.2
Resistant		

Kemb 10	21	6.2
Bungoma	37	10.9
No pests and diseases	54	15.9
Total	**339**	**100**

Source: Researcher, 2015

5.3.3 Source of Clean Planting Material

From the study, most of the farmers (44.2%) obtained planting materials from their own multiplication, 30.4% obtained their planting material from KALRO Embu while 25.4% obtained them from the other farmers (Table 5.6). Farmers (44.2%) originally obtained a few vines from KALRO, which they multiplied in their own farms in order to obtain planting materials for the next season. Key informants from the KALRO confirmed that this form of recycling has its challenges in that at times it becomes difficult for farmers to select materials, which are free from pest attack (weevil). Those who obtained their planting material from KALRO (30.4%) showed that, they were more empowered on the need to have clean planting material for sweet potato production, resulting to increased yield. The rest who obtained them from the other farmers (25.4%) recorded low yield as a result of planting poor quality vines, which spread on the ground producing low quality tubers which had fibrous fresh.

This also posed a great challenge in that if farmers obtained infected vines, all the farmers would have poor yield or no harvest at all due to weevil attack that spread throughout their neighbouring farms. Those who obtained the materials from KALRO were advised on proper cultural practices on how to avoid weevil infestation. They also acknowledged that planting material was scarce thus the government obtained them from neighbouring counties (Meru, Kirinyaga, Nyeri and Western). Similar research work done acknowledged scarcity and poor selection of clean planting material (Maling'a *et al.,* 2013). A recent study by Mazuze (2005) in Mozambique discovered that specific factors affected acceptance of the Orange Fleshed Sweet Potato and comprised inaccessibility of vines and extension service. Farmers who planted certified vines from KALRO were assured of using clean planting material, which increased yield. Those who planted uncertified vines mainly sourced them from other farmers or own multiplication thus, may not have been able to identify those attacked by pests or with other deformities. Key informants from KALRO confirmed that vine cutting is the most recommended method because it is free from soil borne diseases, gives more yield and tubers

produced are of uniform shapes and size. Quality and scarcity of planting material has been a great challenge for sweet potato production.

Table 5.6: Source of Clean Planting Material

Source of Planting Materials	Frequency	Percentage (%)
KALRO	103	30.4
From other farmers	86	25.4
Own multiplication	150	44.2
Total	**339**	**100**

Source: Researcher, 2015

5.3.3.1 Planting Season

Most of the respondents indicated that October was the time of the year when they planted sweet potato and this was at 26.8%. Farmers who had adopted irrigation thus planted all year round were at 25.4%. Others planted in April (23.6%), March at 19.5% and September 4.7% (Table 5.7). Farmers were counselled by the government extension officers to plant the vines 2-3 weeks after the onset of rains, this was to enable increased yield and prevent pests' attack on the roots and vines in the dry period thus affecting the quality of vines, which adversely affected the yield.

Table 5.7: Planting Season

Planting Season	Frequency	Percentage (%)
March	66	19.5
April	80	23.6
September	16	4.7
October	91	26.8
All year round	86	25.4
Total	**339**	**100**

Source: Researcher, 2015

5.3.4 Irrigation, Ridging and Technology Use

The study confirmed that 13.0% of the farmers had adopted irrigation as a modern technology while 56.6% had adopted ridging and use of certified vines (30.4%) (Table 5.8). Farmers from Njukiri, Nthambo, Kamiu and Nembure sub locations grew their sweet potatoes under irrigation thus planted all year round. The source of water was borehole. Irrigation greatly suppressed weevils attack on the vines and tubers thereby increasing yield. Previous research by IFPRI (2014) recommended that investing in drip irrigation makes agriculture more resilient in the face of climate change. Farms that are more productive also tend to use less water per unit of crop produced. This technology can also improve agriculture's water use efficiency while still supporting higher productivity.

Table 5.8: Modern Technologies Used

Modern Technologies in Use	**Frequency**	**Percentage (%)**
Irrigation	44	13.0
Certified Vines	103	30.4
Ridging	192	56.6
Total	**339**	**100**

Source: Researcher, 2015

5.3.4.1 Factors Influencing Technology Use

As confirmed by KALRO, the type of technologies used depended on ecological factors like the soil type and drainage. In light soils, farmers were recommended to plant on flat ground while in heavy soils planting was on ridges. In poorly drained soils planting on moulds was recommended for ease of drainage of excess water. Sweet potato is exhaustive of potassium. High fertility can result in excessive vegetation development at the expense of tuber and starch formation. The important soil physical and cultural factors that affected sweet potato production include soil temperature, rooting depth, method of seedbed preparation and soil erosion, which may result in loss of soil fertility. Sweet potato acts as cover crop therefore reduces soil erosion.

Intercropping sweet potato with maize decreases erosion by a half and mulching can even minimize the erosion losses to zero. The agro ecological zones also affected production. In warmer areas of UM3 and UM4, sweet potato yield was lower due to water scarcity and

weevil attack thus limiting the technology used. The agro ecological factors entail altitude, temperature and rainfall. Ridging technology was common to all agro ecological zones as it increased yield. According to KALRO, the sweet potato varieties common to all agro ecological zones were Kenspot 2, 3, 4, Kemb 10 and Bungoma that were high yielding. KSP 20, SPK 004, Kemb 23 and Kemb 36 did well in UM3 and UM4, which are warmer regions.

The socioeconomic factors looked at were the age, gender, education level and farm size. Most farmers (42.6%) were aged between 50-64 years. Gender involved in production was women (65%). Women are involved in marketing and value additions thus play a crucial role in rural economy through agricultural activities. Education and years of farming knowledge play a vital part in technology acceptance, 38.9% had attained primary education, while 27.4% secondary education, 27.1% tertiary education while 6.5% had no formal education. Most farmers were not well informed with up- to- date information on new farming techniques and technologies, which would enable them grow sweet potatoes efficiently and economically. Farm size also determined the technologies used by farmers. Majority (72.7%) had small land sizes of between 0-0.5 acres thus affecting yield. 27.2% had larger farm sizes (0.51-1 acre and 1.1-1.5 acre) thus grew for both household and commercial purposes.

They had readily adopted modern technologies like irrigation, use of certified planting materials of improved varieties and ridging which increased yield. Institutional factors also affected use as most government agencies, KALRO and the Ministry of Agriculture had scarce clean planting material thus could not meet the demands of all the farmers. They at times sourced vines from neighbouring Counties and by the time they distributed to farmers the rains had subsided predisposing the vines to weevil attack and subsequent losses. Other factors that affected the use of a technology were the ethical, cultural factors the norms and wealth of farmers influenced adoption. Similar research work done by (Strauss *et al.,* 1991) on factors that influence technology adoption decisions highlighted that acceptance choices are influenced by a various socioeconomic (age, gender, education, farm size), demographic, ecological (rainfall, temperature, altitude and agro ecological zones) and institutional factors (Institutional contacts and Extension services) and are dependent on the technology.

Some social cultural dynamics that may drive or inhibit technology adoption are individual elements, which comprise the characters of inventors and promoters/ early adopters, ethnic influences are characterized by doubt evasion and individuality (Kalliny & Hausman, 2007). The worth of the person is critical to invention acceptance. Therefore, there is a crucial want

to examine the consequence of cultural characteristics on the invention dissemination procedure. Uncertainty Evasion is a vital cultural dimension that impacts invention acceptance (Kalliny & Hausman 2007; Perez-Alvarez, 2009).

Individualistic and Collectivism is a critical issue that touches on creation approval (Chandrasekaran & Tellis 2008; Flight *et al.,* 2011, Dwyer, Mesak & Hsu, 2005). Culture is believed to have an important part in the novelty distribution development.

5. 4 CHALLENGES TO SWEET POTATO PRODUCTION AND MITIGATION OF CHALLENGES

Water scarcity was indicated as a major challenge by 32.7% of the farmers interviewed. Pest infestation especially weevils (23.3%), moles attack (12.7%), and price fluctuations was at 11.5% were also mentioned as challenges to sweet potato production. 10.6% never experienced any challenges, poor market for the products was at 7.4%, while lack of transport to the market was the lowest with 1.8% (Table 5.9).

Table 5.9: Challenges to Production

Challenges of sweet potato farming	**Frequency**	**Percentage (%)**
Pest infestation	79	23.3
Price Fluctuations	39	11.5
Poor Market for the products	25	7.4
Water Scarcity	111	32.7
Lack of transport to the market	6	1.8
Moles	43	12.7
No challenges	36	10.6
Total	**339**	**100**

Source: Researcher, 2015

5.4.1 Water Scarcity

Water scarcity was due to lack of adequate rainfall and supplementary irrigation water. There was water rationing by the Itabua Muthatari Water Society. Thousands of litres of water supplied in various homesteads within Embu County by this society go to waste due to lack of storage facilities among a majority of consumers who are low income earners thus largely

depend on wells and boreholes for water supply. This Water Society is a community water project which supplies water directly tapped from Kapingazi River to consumers once or twice a week depending on the levels of water at the river. Water scarcity greatly reduced yield and predisposed the vines and tubers to weevil attack, during periods of prolonged dry spell. To curb water scarcity most farmers (20.1%) have adopted the method of planting during the rainy season to prevent weevil damage and planted early maturing varieties to curb drought effects (Table, 5.10).

5.4.2 Pests Infestation and Moles Attack

To increase production and reduce pest attack, the farmers (10.0%) sowed when rains had begun and reaped in a timely manner. Other farmers (4.4%) practiced mulching during the dry seasons. This prevented soil moisture loss that could lead to cracking of the soil exposing the tubers to weevil attack. Moles attack led to great losses as they exposed the tubers leading to wastage and predisposed them to weevil attack. To curb this, (19.2%) of the farmers built traps (Table, 5.10).

Table 5.10: Mitigation of Challenges

Response	**Frequency**	**Percentage (%)**
Mulching	15	4.4
Irrigation	68	20.1
Planting during the rainy season	68	20.1
Building traps for moles	65	19.2
Timely harvesting	34	10.0
No challenges	89	26.2
Total	**339**	**100**

Source: Researcher, 2015

5.4.3 Poor Selection of Vines

Poor selection of planting material also led to decreased yield as reported by most farmers. The poor varieties selected and planted by farmers had small vines (fibre) which produced roots that spread over a long range and only produced little tubers or yield at all. As observed in the field, these varieties also had scorched leaves resulting to no harvest. There was also lack/scarcity of certified planting material as most sourced from fellow farmers. This limited access to the planting material thus resulted to high costs of purchasing (1 vine is sold at

Kshs.2). Most farmers thus sort advice from KALRO on better sweet potato management practices and buying certified planting materials for greater production.

Majority of the farmers never experienced any problems due to proper agronomic practices like; the planting of certified materials and adoption of irrigation, which enabled them, grow their sweet potatoes all year round and suppressed attack by weevils, resulting to larger tubers and increased yield. The key informants highlighted drip irrigation as the best technology that conserves water but it is not readily adopted in the study area because it is very expensive for most peasant farmers. Similar research work done by Attaluri (2013) in India noted that, obtainability of certified vines on sustainable base was the main limitation.

5.4.4 Lack of Knowledge and Skills

Some farmers also lacked knowledge and relevant skills when planting. Others had no idea of how to respond to the major challenges affecting sweet potato production due to illiteracy. Extension officers from the Agricultural Ministry addressed this by setting farm field days to empower farmers on sweet potato production benefits through value addition. This is a government project termed as “Kilimo Biashara” that seeks to address sweet potatoes as a slow food and train on pre-harvest and post-harvest technologies and value addition.

5.4.5 Price Fluctuations and Lack of Capital

Price fluctuations greatly affected sweet potato production. When the produce is readily available, the prices are lower while when production is scarce, the prices go higher. During the period of surplus, there are usually low market prices set by brokers for the produce. Some farmers acknowledged that lack of capital prevented them from purchasing certified planting material. They sourced from other fellow farmers.

5.4.6 Poor Market for the Products and Lack of Transport to the Market

This was also highlighted as a challenge. Many farmers confirmed that there was lack of an organized marketing system thus resulting to low market prices for their tubers. For the low markets, farmers looked for the highest buyers and sought for better markets from other farmers. Lack of transport to the market was also a challenge as most farmers are poor thus only rely on brokers to buy their produce directly from their farms and in return result to extortion of these farmers.

Wambugu (2003) also emphasized the key constrictions to production as the extensive usage of low yielding and late-maturing outdated varieties and the consequent absence of certified vines. According to Kapinga (2004), the major reasons given for decreasing production trends in Tanzania were labour and land shortages, difficulties in getting planting material, drought, pests and diseases, and illness or old age of key members of the family. In areas where farmers reported an increasing trend in sweet potato production, the factors mentioned included increase in the area under cultivation, use of high yielding varieties that are drought, pests, diseases resilient and improved market opportunities.

5.5 EFFECTS OF SWEET POTATO PRODUCTION TO HOUSEHOLDS

5.5.1 Yield Harvested per Variety and Area

Majority of the farmers stated that 4-10 bags /0.25 acre were the yield in kg/acre per variety (40.1%), while 21.5% of the farmers did not know the yield harvested per variety. In addition, 2.7% reported that they failed to have any harvest from sweet potatoes while 18.3% harvested 70-90 bags per variety and 17.4% harvested 15,000-20,000 bags (Table 5.11). In addition, 21.5% of the farmers did not know the amount of yield because they never kept records of the yield as they harvested through piecemeal thus it was difficult to estimate the yield. They mainly grew their sweet potatoes for household consumption, while 2.7% reported that they failed to have any harvest due to severe attack by weevils, which tend to invade fields that are not well watered especially during the dry season (Table 5.11). Farmers who had yield of 15,000-20,000 bags mainly grew the Kenspot 2, 3, 4 and Kemb 10 varieties, and had adopted irrigation technology. The other farmers with 40.1 % and 18.3% mixed the different varieties in small portions of their lands.

Key informants gave a standard yield of 15,000-20,000kg per acre when proper agronomic and cultural practises are adopted. They also highlighted that continuous planting of sweet potatoes on the same piece of land over a long period of time reduced land productivity resulting to reduced or no yield. This is due to bacterial attack and destruction of the soil structure. High yield is because of proper practices during the course of production process (Maling'a *et al.*, 2013).

Technologies adopted greatly affected the yield. Farmers who had adopted irrigation, use of certified vines and ridging had larger harvests as presented in Table 5.9. Farmers who harvested 4-10 bags per variety had farm sizes of 0.25 acres while those with 70-90 bags per

variety had farm sizes between 0.51-1 acre. Those who harvested 15,000-20,000 bags had 1.1-1.5 acres (Table 5.11). Similar research done by Gutiérrez *et al* (2003) in Peru noted that, the aphid-transmitted *Sweet Potato Feathery Mottle Virus* did not expressively distress the produce of the sweet potato cultivars but attack of the cultivars by the whitefly-transmitted *Sweet Potato Chlorotic Stunt Virus* was linked to substantial crop decrease. Double contamination led to in Sweet Potato Virus Disease resulting to yield reduction. Gibson *et al* (2007) also highlighted that the Sweet Potato Virus Disease (SPVD) greatly reduced sweet potato yield in Uganda.

Table 5.11: Yield per Variety and Area

Sweet potato Yield(kg/acre)	**Frequency**	**Percentage (%)**
4- 10 (100kg) bags /0.25 acres	136	40.1
70-90 (100kg) bags per variety/acre	62	18.3
15,000-20,000 (100kg) bags per variety/acre	59	17.4
NO harvest due to attack by weevils	9	2.7
I don't Know	73	21.5
Total	**339**	**100**

Source: Researcher, 2015

5.5.1.1 Effects of the Technologies on Sweet Potato Yield

The study findings, all the farmers acknowledged that the technologies they had adopted increased yield, enabled larger tuber production and elimination of pests' leading to faster growth. Planting of sweet potato vines on ridges enables easier root formation, easier weeding and less damage of tubers at harvesting. This technology also allows for easy pest control (lowers weevil damage) and prevents soil erosion thus improves the soil structure. Ridging also allows for expansion of the tubers giving higher yield. Ridging technology was also accompanied by mulching which allows for soil moisture retention thus preventing cracks, which expose the tubers to attack by weevils and minimizes soil erosion. Most farmers who had adopted ridging also dug furrows and bench terraces, which are cultivation techniques that helped conserve water by preventing soil erosion during watering and in the rainy seasons and effective weed control. Irrigation suppressed weevil attack. Larger tubers were also produced because of these technologies.

Pests' elimination led to increased yield and better tubers size and appearance. Faster growth was due to adoption of clean planting materials that were early maturing varieties. All the respondents indicated that modern technologies affected sweet potato production as they increased yield. Similar research done by Agbede (2010), in South-western Nigeria recommended mixing of inorganic fertilizer (CAN and DAP) with organic manure improved soil fertility resulting to enlarged tuber harvest. Research done by Wang *et al* (2009) in China highlighted that surface mulching can increase volume of available water in soil and other soil management practices. This system produced higher biomass yield.

5.5.2 Income from Sweet Potatoes

Majority of the farmers (42.8%) earned an income of over Kshs.10, 000, while 31.3% did not indicate the amount of income generated from sweet potato production at household level. Those earning an income of between Kshs. 5,000-10,000 were 10.9%, farmers earning less than Kshs. 4,999 were at 10.6% and farmers who grew the sweet potatoes for personal consumption were 4.4% (Table 5.12). This confirms that sweet potato production can be a very lucrative venture if farmers are well informed on the proper agronomic practices, and the major benefits that come with the adoption of modern production technologies. Most of these farmers with greater income supplied their sweet potatoes in schools, government institutions and to other fellow farmers who carry out value addition (processing sweet potato into products like sweet potato flour for cakes, porridge and crisps).

Farmers who never earned an income (31.3%) never sold their sweet potato and only grew for household consumption. They also practiced piecemeal harvesting which also made it difficult to account for income generated whenever they made any sales. Farmers with farm sizes between 0.25 to 0.5 acres of land earned an income of between Kshs. 5,000-10,000 per planting season while those with larger farm sizes of 0.51-1 acre and 1.1-1.5 acres earned over Kshs. 10,000. Farmers with farm sizes of about 0.125-0.25 acres earned less than Kshs. 4,999 (Table 5.12). A bag of sweet potatoes (100kg bag) goes for Kshs. 1,200. This pricing and income generated depends on the season. Most farmers with 0.51-1 acre and 1.1-1.5 acres of land had adopted irrigation technology which enabled them grow sweet potatoes all year round. In a year, they made more than Kshs. 120,000, those with 0.25- 0.5 acres earned between Kshs. 5,000-10,000 amounting to Kshs. 60,000-120,000 per year while those with 0.125-0.25 acres earned less than Kshs. 4,999 amounted to Kshs. 59,988 annually.

Table 5.12: Income Generated from Sweet Potato Production.

Income Generated Per Season	Frequency	Percentage (%)
Less than Ksh. 4,999	36	10.6
Between Ksh. 5,000- 10,000	37	10.9
More than Ksh 10,000	145	42.8
For personal consumption	15	4.4
Never earned an income	106	31.3
Total	**339**	**100**

Source: Researcher, 2015

5.5.2.1 Marketing System and Pricing of the Sweet Potatoes

From the findings, majority of the farmers indicated that there was no marketing system for sweet potato production (84.8%) while 15.2% confirmed that there was a marketing system. When there is an oversupply, selling is done through farmer groups. When the demand is high and the product is in low supply, selling is done directly in markets. The farmers who indicated lack of a marketing system usually sell their produce to brokers at their farm gates. During the months of May and June, sweet potatoes are scarce thus they become very expensive. Most farmers produce and consume sweet potatoes at household level hence the marketing system is irrelevant. An organized marketing system can fetch better prices and selling of produce through brokers reduces prices.

Sweet potato markets as per the findings of the study, 61.7% never sold their produce, 20.0% directly sold their produce to the nearest market, while 18.3% sold to brokers (Table 5.13). Majority of the farmers grew their sweet potatoes for only household consumption and never sold their produce. Farmers who sold to brokers at farm gate indicated that they bought their produce at lower prices thus extorting the farmers. Those who sold directly in the market indicated that there were fluctuations in prices depending with the season. Signs of weevil damage also affected the price (fetched low prices) in the market. To improve the sweetpotato value chain all the actors are to be included from input providers (suitable varieties of certified vines) to growers, dealers, customers, the institutes or guiding framework which constructs the mode in which contacts ensue in the sequence and the service providers, comprising examination and improvement organizations, who support in advancing its operation.

Discerning market gaps and prospects would help advance production and allow for easy acceptability for instance in institutional feeding programs. Come up with branding

procedures, as this would enable urban users to change their view and embrace the sweet potato varieties like the orange fleshed as a healthier crop. By also reaching out to the high salary category this will help change the way sweet potato is perceived. Marketing leads to value addition and provides an alternative source of livelihood for the grower.

Table 5.13: Where Sweet Potatoes are Sold

Where Sweet Potatoes are Sold	Frequency	Percentage (%)
Personal selling to nearest market	68	20.0
Sell to the brokers (middlemen) at farm gate	62	18.3
Home consumption	209	61.7
Total	339	100

Source: Researcher, 2015

5.5.3 Other Benefits from Sweet Potato Production

One of the major benefits that farmers indicated was the use of sweet potato vines and leaves as fodder for domestic animals this stood at 45.1%, 35.1% of households consumed it as food thus was a source of food security, while 10.0% planted it to act as a cover crop. Income and selling of vines was at 9.8% (Table 5.14). Both the vines and leaves have a high protein and mineral content thus used as supplementary fodder. Sweet potatoes were stored and used as a food security crop when maize was scarce. It also acted as a good cover crop thus helped improve soil texture.

The interviews conducted on government officials (Research and Extension field officers) from KALRO and the Ministry of Agriculture in Embu confirmed that sweet potato planting material is very scarce. KALRO is not able to meet the demand for vines in the entire County. KALRO has to source for more planting material from the neighbouring Counties of Meru, Kirinyaga, Nyeri and Western Kenya. This limited access to the vines thus makes purchasing very expensive for most farmers who are poor, therefore cannot afford the clean planting material, which is sold to them by KALRO for Kshs.2 per vine or 1kg at Kshs.50.

Table 5.14: Other Benefits from Sweet Potato Production

Benefits	Frequency	Percentage (%)
Feeding of livestock (Fodder)	153	45.1
Food security	119	35.1
Income, selling of vines	33	9.8
Cover crop	34	10.0
Total	339	100

Source: Researcher, 2015

5.6 ROOTS AND TUBERS POLICY

Key informants interviews from the Ministry of Agriculture confirmed that there was no government policy with respect to sweet potato production technologies. The available policy is a draft document (Roots and Tubers Policy, 2010). The improved varieties are accessible from KALRO and other farmers though a small fee is required to obtain the clean planting material. Their reasons for selling the vines to farmers is to enable the farmers to adopt the culture of nurturing the vines for the next season through own multiplication as the materials are scarce and difficult to source.

5.6.1 Agricultural Policy in Kenya

The Strategy for Revitalizing Agriculture- SRA (2004-2014) recognizes that to have maximum smallholder farm output and also advance salaries, this form of husbandry needs be transformed from growing the crop for only domestic uses but also for profit making ventures. This will be appealing to the private sectors to channel their resources towards provision of current production techniques that will lead value addition through advanced yield. Inaccessibility to finances, unorganized market systems and institutions also inhibit the rate at which an invention will be acceptable thus influence yield and leads to price swings affecting earnings. The private entities can capitalize on manufacturing while local authorities in cooperation with the private industries can come up with storage reservoirs and add value.

Irrigation use is less than 7% which if accepted can lead to high yield. This technology is used in large-scale rice irrigation schemes. There is need to train farmers on the benefits of taking up irrigation as it will advance harvest and curb drought effects. Capacity building on agro-processing will add value to the product thus improve farmer livings. Colonial policies

largely concentrated on cash crops neglecting the traditional food crops thus affecting their intake. Small-scale farmers earn very little from their produce thus resulting to the authorities introducing inputs that were not economical to the growers. Research was uncoordinated but with the introduction of national experimentation council, many extension officers have been trained and help in dissemination of new knowledge. not coordinated, until the creation of the national scientific and research council. Scarcity of funds has also led to provision of poor and low yielding planting materials to farmers. Much emphasis has been placed on export crops rather than the vital crops.

5.7 Hypothesis Testing (Null Hypothesis)

H_0: There is no association between the technology applied and the sweet potato yield.

For Objective 1, the questions that were cross tabulated were: which modern technologies (use of irrigation, use of certified vines, and ridging) are used? and do the technologies used affect sweet potato yield? Correlation coefficient (Simple Correlation) analysis was carried out on the cross tabulated results to test the relationship and measure the degree of association between the two variables as shown in table 5.15 and 5.16.

Table 5.15: Cross Tabulation of Modern Technologies Used and Effects of Technologies on Sweet Potato Yield

		Effects of technologies on sweet potato yield			Total
		Increased yield	Faster growth	Eliminate pests and diseases	
Modern technologies used	Irrigation	27	2	1	30
	Certified Vines	58	9	9	76
	Ridges	122	3	28	153
Total		207	14	38	259

Source: Researcher, 2015

5.7.1 Simple Correlation Analysis

The study used Pearson's R to measure the strength of the relationships between two variables i.e. the independent and dependent variable. The correlation coefficient r is 0.129 at

0.05 significance level. The results confirm that there is a low positive association between the technologies used and their effects on sweet potato yield. According to correlation coefficient, the r value range between +1 and -1. In this study, the r-value is 0.129 denoting a low positive relationship between the two variables (Table 5.16). The study therefore rejected the null hypothesis and adopted the alternative hypothesis (H_1) 'there is a relationship between the technology applied and the sweet potato yield'. The results show that there is a relationship between the technology applied and the sweet potato yield in the study area. Therefore, the technologies used are effective in increasing the yield.

The farmers who had adopted irrigation as a modern technology of production (13%) attested to increased sweet potato yield. This helped suppress weevils attack during the dry season (Table 5.11). This technology coupled with proper agronomic practices like sourcing for clean planting material certified by KALRO, and adoption of improved sweet potato varieties like Kemb 10, which is drought resistant, and Kenspot 2, 3 and 4, which are early maturing resulted to larger tuber production hence increasing the yield. The study also indicated that majority of the farmers (56.6%) had adopted ridging technology. This helps in easier root formation, weeding, easier pest control, prevents soil erosion and enables easier harvesting. The use of this technology allowed for tuber expansion resulting to increased yield (Table 5.8).

Farmers who used both certified vines and irrigation had larger yield due to suppressed weevil attack. This is because pests like weevils and aphids resulted to diseases like Alternaria blight and Sweet potato Feathery Mottle Virus, which mainly attacked the vines leaves. The Key informants interviews from KALRO and the Ministry of Agriculture confirmed that Alternaria blight is considered the most common fungal disease in East Africa. This is characterised by black lesions appearing on the petioles and stems. The disease and lesion size increase as altitude increases. Infection and sporulation is as a result of planting infected planting materials, wind, splashing rain and water. This disease affects sweet potatoes in all agro ecological zones in the study area. This can be controlled through planting of pathogen free planting material of the more resistant varieties. The Sweet Potato Feathery Mottle Virus is also controlled through use of pathogen free planting material.

Table 5.16: Simple Correlation Analysis

Correlation

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Interval by Interval	Pearson's R	.095	.051	1.524	.129[c]
Ordinal by Ordinal	Spearman Correlation	.048	.058	.771	.441[c]
N of Valid Cases		259			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Source: Researcher, 2015

CHAPTER SIX: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter consists of summary, conclusions, and recommendations derived from the findings of the study. The first section provides a summary of the key outcomes of the study concerning the objectives of the study. Section two discusses the conclusions based on the findings of the study. The last section provides recommendations to policy makers and for further studies.

6.2 Summary of Key Findings

Objective 1: Production Technologies Currently in Use

Production technologies used by farmers in Manyatta Sub County have greatly affected sweet potato yield. They include fertilizer application, improved sweet potato varieties, use of clean planting material, irrigation and ridging. Most farmers never applied fertilizer during production of this crop. This is because the soils are highly fertile. Improved varieties grown by farmers in the study area were Bungoma, which matures early, and produces larger tubers and is readily available unlike the other varieties. Kenspot 2, 3 and 4 are also early maturing varieties together with Kemb 10, which is a more drought resistant variety compared to the other varieties thus does well in marginal areas like the transition zone between UM3 and UM4. Tainung and SPK 004 are orange fleshed (Vita A) thus are rich in beta-carotene. KSP 20 grows in low altitude areas like UM4. Kemb 23 and 36 are local varieties that serve a dual purpose as both food and fodder.

Clean planting material was scarce making it expensive for peasant farmers. This pushed them to source for cheaper and low yielding varieties resulting to reduced yield. Susceptibility, tolerance and resistance of a variety to pests and diseases depended on agronomic aspects and selection of planting materials. Farmers do their own multiplication of planting materials that they originally sourced from KALRO. Others sourced from fellow farmers and this makes it difficult to select pest free vines. The key informants from the Ministry of Agriculture and KALRO confirmed that access to clean planting material was difficult. They sourced their materials from neighbouring counties (Meru, Kirinyaga, Nyeri,

and Western). This study thus confirmed the gap in literature where lack of access to planting material and scarcity rendered vine sourcing to be an expensive venture.

Irrigation was a modern technology adopted that enabled farmers grow sweet potatoes all year round. This also suppressed weevil attack resulting to increased yield. Ridging allowed for expansion of tubers, and made weeding and harvesting easier. Continuous planting of sweet potatoes on the same piece of land led to reduced soil fertility due to bacterial attack and destruction of soil structure. This resulted to low production. The type of technology used depended on ecological factors like soil type and drainage. Soil physical and cultural factors like soil temperature, rooting depth, soil erosion and method of seedbed preparation led to soil infertility thus affecting production. Socioeconomic factors like age, gender, education level and farm size influenced technology adoption and use thus affecting yield. Institutional factors also affected adoption as the government could not meet the planting material demand for all farmers.

Objective 2: Challenges to Sweet Potato Production

Major constraints to production was water scarcity which farmers curbed by planting during the rainy season and planting early maturing varieties to curb drought effects. Pest infestation especially weevils, moles attack, price fluctuations, poor market for the products and lack of transport were also mentioned as challenges to sweet potato production. Poor selection of planting material also led to decreased yield as reported by most farmers. There was also lack/ scarcity of certified planting material as most sourced from fellow farmers. This limited access to the planting material.

Objective 3: Effects of Sweet Potato Production

One of the major effects of adopting the modern technologies is the increased sweet potato yield. Economic benefits of sweet potatoes were the returns. Most farmers with larger farm sizes grew their sweet potatoes for domestic consumption and commercial purposes thus supplementing their household income. Others only planted for household consumption. Sweet potatoes also lack an organised marketing system thus majority of farmers sold their produce to brokers at lower prices. Those who sold directly in the market also confirmed price fluctuations depending on the season. Other benefits are that sweet potatoes act as a

good cover crop, the vines and leaves are rich in minerals thus are used as supplementary fodder. It also acts as a food security crop when maize is scarce.

6.3 Conclusion

Sweet potato production is widely practised in Manyatta Sub County. Farm technologies used by different farmers have greatly affected yield. Technology adoption is influenced by ecological factors like agro ecological zones of the farmers, soil pH, temperature and rainfall and social economic factors like age, which in turn affects adoption and production levels. Most farmers confirmed that adopting modern technologies like irrigation and ridging increased yield by suppressing pests attack. KALRO has introduced improved varieties that are early maturing and drought resistant to farmers. Adoption of improved varieties reduces the cost of production while maximizing on yield.

Access to clean sweet potato planting material is still scarce in the County. KALRO is not able to meet the demand of farmers thus most are not able to access clean and certified planting material. This is because of its slow growth and multiplication nature. This has pushed farmers to do their own multiplication thus many are not able to isolate clean materials from infested ones, making the vines expensive for poor farmers who resort to borrowing vines from fellow farmers. There is also lack of a formal seed system for sweet potato planting material. There is need to increase access to planting material through research so as to increase sweet potato production which would drastically increase food security within Embu County and nationally. The government should therefore come up with a formal seed system for supply of this vegetatively propagated crop. This would improve access to clean planting material resulting to increased yield.

Farmers should also be sensitized on the need to establish small nursery plots and maintaining it to the next season to curb shortage of vines during planting time. They should also adopt a culture of sourcing certified planting material. Drip irrigation is very expensive but the most economically viable and environmentally sustainable technology because it conserves water. If the cost of installing drip were reduced to affordable prices, most farmers would be able to adopt it. Sprinkle irrigation on the hand is largely dependent on consistent water availability. Most farmers also lack information on the best agronomic practices and skills for sweet potato production especially on pests and disease control. Farmers

sensitization would help fill this gap. Farm technologies for sweet potato production have been widely adopted by agronomists in the study area. They have resulted to increased yield, which provide salary for the farm families. Lack of an organized marketing system discourages farmers from venturing into sweet potato production business. This is because many farmers sell their produce to brokers who tend to extort farmers as they buy at lower prices thus affecting the production levels. With proper agronomic practices and adoption of modern technologies, sweet potato production can be a lucrative venture for most farmers within Manyatta.

6.4 Recommendations

This section provides recommendations which are addressed to the policy makers and future researchers.

6.4.1 To Policy Makers

This section is addressed to the policy makers who play a crucial role in addressing national policy issues.

i) The government should come up with a well-developed value chain of sweet potatoes from production to processing as this will promote high income generation thus make sweet potato production attractive to men and not just women leading men to adopt technologies increasing production.

ii) The government should empower farmers through regular field trainings and demonstrations on ways of developing value addition for their products that would change farmer attitude towards economic viability of sweet potato production.

iii) The government should introduce avenues for easier access to clean planting material in all seasons.

6.4.1.1 To the Private Sector or NGOs

i) The private sector should be involved in developing a marketing system and agro industries for value addition of sweet potatoes produce.

6.4.2 To Future Researchers

This section is addressed to future researchers who wish to carry out their research on sweet potato production.

i) A study should be conducted on value addition within the same county, as most farmers are unaware of the great potential and advantages that are as a result of sweet potato production.

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APPENDICES

Appendix I: Questionnaire

My name is Joy Sarah Nkirote Muthuri. I am a Masters student at the University of Nairobi undertaking Master of Arts Degree in Environmental Planning and Management. My research topic is on **the effects of farm technologies on sweet potato production in Embu County.** In order to make my study successful, I need your participation and support. Please, kindly answer the following questions as accurately as possible. Your individual responses will be treated with utmost confidentiality and will be used only for purposes of this study. This questionnaire will attempt to answer the research questions on **the effects of farm technologies on sweet potato production in Embu County.**

SECTION A: DEMOGRAPHIC DATA

Tick inside the bracket of choice.

1. Name:---------- TEL NO: ----------
2. Farmer's Gender: Male [ ] Female [ ]
3. Age: under 18 [ ] 18-35 [ ] 36-49 [ ] 50-64[ ] Over 64 [ ]
4. What is your highest level of education? Primary[ ] secondary[ ] tertiary[ ]

   No formal education [ ]
5. Farm size under sweet potato production----------

6. Agro ecological Zones

Location	
Division	
Altitude	
Rainfall (average)	
Average temperature	
Ecological zone	

SECTION B: PRODUCTION TECHNOLOGIES CURRENTLY BEING USED

Variable 1: Fertilizer Application

a) Do you use fertilizer? Yes [ ] No [ ]
b) If yes which? ----------What amount of fertilizer is applied in Kg? .....
c) What type of fertilizer is commonly used? Organic or Inorganic?
   …….
d) Which is the most effective fertilizer and why?

   …….

   …….

Variable 2: Improved Sweet Potato Varieties (Types)

a) Which varieties of sweet potato do you grow on this farm?

1. …….
2. …….
3. …….
4. …….

b) Which variety is preferred by farmers and why not the others?

1. …….
2. …….

c) Which varieties mature earlier and duration of maturity?

1. ……
2. ……...
3. ……...
4. ……...

d) What are the yield per variety in kg/ha?

1. …….
2. …….
3. …….
4. …….

e) What are the diseases and pests of sweet potato you have observed in your farm?

1. ……...
2. ……...
3. ……...
4. ……...

f) Which variety is more susceptible to pests and diseases?

1. Very Susceptible ……
2. Tolerant …….
3. Resistant ……

Variable 3: Source of Clean Planting Materials

a) Where do you obtain the planting materials?

1. ……..
2. ……..

b) Type and quality of planting material (Is it Certified by the Kenya Agricultural and Livestock Research Organisation or The Ministry of Agriculture)?

……

c) What time of the year do you plant your sweet potato?

……

d) What is the quantity (amount) of planting materials?

……

……

Variable 4: Technology Use

a) Other modern technologies you have adopted?

1. …….....
2. ……
3. ……
4. ……....

b) What factors influence technology use?

1. ……..
2. ……..
3. ……..

SECTION C: CHALLENGES TO SWEET POTATO PRODUCTION

What are the challenges to sweet production in this area?

1. ……...
2. ……...
3. ……...
4. ……...

e) What is your response with regards to the problems mentioned above?

1. …….
2. …….

SECTION D: EFFECTS OF SWEET POTATO PRODUCTION TO HOUSEHOLDS

Variable 1: Yield

a) Do the above-mentioned technologies affect sweet potato production yield?

Yes [ ] No [ ]

If yes how?

1. ……
2. ……...
3. ……...
4. ……...

b) What amount (yield) of sweet potato is harvested per area?

1. ……

……

Variable 2: Income

a) How much income is generated from sweet potato production at household level?

1. …….
2. …….

b) Is there any marketing system for sweet potato production? Yes [ ] No [ ] If so does pricing affect household production? Yes [ ] No [ ]. Explain your answer.

1. ……..
2. ……..

c) What other benefits do you get?

END. THANK YOU FOR YOUR TIME

Appendix II: Interview schedule for Government Organisations (KALRO, Ministry of Agriculture)

1. What is the government policy with respect to sweet potato production and technologies in Manyatta, Embu County?

……...

……

2. How effective are the set government policy?

Very effective ( )

Effective ( )

Not sure ( )

Not effective ( )

3. How do you suggest Government Policy affects sweet potato production?

…….....

…….

4. Are the improved planting varieties easily accessible and readily adopted by farmers?

Yes ( ) No ( )

Explain……

…….

5. What types of planting varieties are adopted by farmers?.....