

**ASSESSMENT OF THE EFFECTS OF GREENHOUSE FARMING ON FOOD  
SECURITY AT IKUTHA SUB-COUNTY, KITUI COUNTY**

**BY**

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**A RESEARCH PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE  
REQUIREMENT FOR THE DEGREE OF MASTERS OF ARTS IN ENVIRONMENTAL  
PLANNING AND MANAGEMENT OF THE UNIVERSITY OF NAIROBI**

**2018**

## DECLARATION

I wish to declare that this research study paper is my own original work and first of its kind. It has not by any chance been presented to any other academic institution of learning in fulfilment of a course requirement or for a degree at any other University or for any other purpose whatsoever.

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## **DEDICATION**

I dedicate this research project report to my late Mom. Her dreams for me have resulted in this achievement and without her loving upbringing and nurturing; I would not have been where I am today and what I am today. Had it not been for my mother's unflinching insistence and support, my dreams of excelling in education would have remained mere dreams. I thank my mother with all my heart and I know she is up there, listening, watching over me and sending me her blessings constantly and is my guardian angel.

## **ACKNOWLEDGEMENTS**

First and foremost, I thank the super powerful God for his showers of blessings which saw me finish this work successfully.

I wish to express my sincere gratitude to my husband, Daniel Mwanzia, my daughter Maya Mwanzia, my son, Klay Mwanzia for granting me moral support and encouragement throughout my study.

I am equally honoured to appreciate the chairman, Department of Geography & Environmental studies at the University of Nairobi, who doubles up as my project supervisor, Dr. Boniface Wambua and Dr. Alice Odingo for their unreserved effort, technical guidance and advice in writing this project.

My sincere gratitude goes to my sister Christine Kyembeni who has financially and emotionally supported me during my study period. May God bless you and amplify your boundaries.

I would like to thank my enumerators Gladys Munyao, Deborah Mumo, Paul Masumba and Musyoka Kamonyi for their dedication during the data collection period. Am grateful too to the transport team who were punctual and drove safely.

Special appreciation to the agricultural officers-Ikutha Division (Ministry of Agriculture), Dorcas Aid International(DAI) coordinators, Kitui County Government officials, Ikutha local administrators and Kitui South farmers for their unreserved contributions towards the success of this research.

Lastly, I would like to recognize the input of my colleagues as well as friends who by virtue of their proximity, served as my first point of consultation.

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## ABSTRACT

Food insecurity in Kenya continues to rise due to inflated food prices, civil and political unrest, recurrent seasons of failed or poor rains, prolonged high food prices, environmental degradation, outbreak of diseases and flooding. Population increase has largely contributed to shortage of food globally. In order to meet the food needs of the increasing population, countries globally have come up with agricultural technologies for example genetically modified foods (GMOs), greenhouse technology, use of drones, agricultural robots and remote. The study sought to assess the effects of greenhouse farming technology on food security at Ikutha area. Ikutha being an ASAL region has been receiving inadequate rainfall that leads to food insecurity. Due to unpredictable weather patterns, greenhouse technology which involves controlled environment for crops was introduced in this area by government and non-governmental organizations. The study was led by the following objectives; to compare the productivity before and after the greenhouse adoption, to compare the income of the farmers before and after greenhouse adoption, to identify challenges faced by the farmers after greenhouse adoption and to make recommendations for addressing the challenges. Methods of data collection used included questionnaires, observation, interviews and documentary review. Data analysis and presentation in this study focused on frequencies, T-test, tables, graphs, and percentages. Response rate was 62% with over 70.5% of farmers being 38 years and above. Male farmers contributed to 51% of the respondents. It was observed that about 9.5% of the respondents had experienced food insecurity. Productivity and income changed after greenhouse adoption as the null hypothesis on production before being the same as production after greenhouse adoption was rejected. About 73.2% of the farmers had their farming land above 5.0 acres with 97.4% indicating that farmers received more income after greenhouse adoption. The study results showed that the uptake of greenhouse technology has however been low with lack of water (33.3%) and cost of greenhouse installation (16.7%) and maintenance being cited as a major obstacles. This study found out that there is an increase in income and yields for those who have adopted the technology. Some of the major challenges identified in this study include lack of adequate water (33.3%), high cost of greenhouse, high cost of customizing the greenhouse, high cost of maintenance of greenhouse and reluctance of Ikutha farmers to adopt the technology. This study recommends that Kitui County government intervenes by ensuring greenhouse technology is well known and understood by Kitui farmers. There should be incentives from the Kitui County Government for those who choose to adopt it for example affordable greenhouse materials, seeds, pesticides, seminars for training and also markets for their produce. National government in collaboration with county government can find a way on how to solve the issue of inadequate water. They can build water pans, dams, wells, provide tapped water which can be used in farming. For those who don't have storage containers for harvested rain water can be provided.

## **LIST OF ACRONYMS & ABBREVIATIONS**

**ADRA-** Adventist Development and Relief Agency

**AFK-** Amiran Farmer's Kit

**ASAL-**Arid and Semi-Arid Lands

**CC-**Climate Change

**DIA-** Dorcas International Aid

**FAO-**Food Agricultural Organisations

**FBO** -Faith Based Organizations

**GMOs-**Genetically Modified Foods

**GOAL-** Global livelihoods' agency

**IFAD** - International Fund for Agricultural Development

**IPCC-** Intergovernmental Panel on Climate Change

**KALRO-**Kenya Agricultural Livestock Research Organizations

**Ksh.** -Kenya Shillings

**NGO-**Non-Governmental Organisations

**SASOL FOUNDATION-**Sahelian Solutions Foundation

**UN-**United Nations

**US-**United States

**WFP-**World Food Programme

**YEDF-**Youth Enterprise Development Fund



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## **CHAPTER ONE: INTRODUCTION**

The chapter introduces the study focusing on the background of the food security problem and the possibility of using new agricultural technology of greenhouses in alleviating the problem. Objectives, research questions, and hypothesis were also covered. Justification of the study, the scope of the study and assumptions made on the study.

### **1.1 Background of the study**

Agriculture is a leading sector in the Kenyan economy, contributing 24% directly and 27% indirectly to the Gross Domestic Product (GDP) (Hope 2017). The Kenya Vision 2030 for Agriculture is to promote an innovative, commercially oriented and modern agriculture (Government of Kenya, 2008). The initiative has been supported by among others, the Economic Stimulus Programme (ESP). ESP has promoted agriculture through funding and providing conducive environment for promoting agriculture. The government has reinforced this by putting in place Economic Stimulus Programme (ESP) to boost the country's economic recovery and offer solution to the challenges of food security among others. WHO (2008), in its report indicated that poverty declines by two percent in every one percent increase in agriculture. The greenhouse technology has been proved profitable and preferable to the open-field system, elsewhere in the world (Desprez, Easdown & Ali 2018). Farmers have adopted the use of greenhouse as a new technology in agricultural production to increase food production in their farms. This has resulted to increased yields and income for the farmers. Farmers also have been able to harvest varieties of crops any time of the year thus no more dependent on seasonality.

Adoption of this technology is expensive for small-scale farmers (Lotter 2018). This is because these farmers do not have knowledge on good farming techniques and are incapable of implementing new technologies appropriately. They also do not have capital to start and sustain their agricultural enterprises, as well as markets for their products so as to generate sufficient income. Food crops grown include vegetables such as tomatoes, kales, spinach, carrots, sweet potato, cassava, Irish potatoes, and cabbages among others. Greenhouses can be adopted in those regions that receive low rainfall and where other climatic factors are insufficient such as humidity, radiation and presence of infertile soils, which cannot be used for farming (Desprez, Easdown & Ali 2018).

A greenhouse is a structure with walls and roof made of transparent material which is heated artificially and allows natural light for plant growth. It's made from transparent materials such as glass, in which crops requiring regulated climatic conditions are grown (Despretz, Easdown & Ali 2018). Greenhouse can also be called glasshouse or hothouse. These structures range in sizes from small sheds to industrial-sized buildings. A miniature greenhouse is known as a cold frame.

The invention of greenhouse was due to the demands to produce better quality and a higher economic value crops (Pariyar et al. 2016). The invention has also been greatly steered by the unfavourable climatic conditions, which at natural conditions some crops cannot grow all year round (McMahon, 2000). This is brought about by inadequate rainfall, high or low humidity, among other climatic conditions. Due to these demands many farmers use greenhouse technology to produce their agricultural goods. Marshall (2014), in his work titled "Manual for simple greenhouse", gave benefits of adoption of greenhouse, which includes; early maturity of plants due to high temperatures, effective pest and disease control at reduced costs, reduced residual because of less chemical used, high yields, reduced risks and uncertainties, weed control and all year round production.

Spain is one of the largest greenhouse complexes in the world (Galdeano-Gómez, Aznar-Sánchez & Pérez-Mesa 2011). It is sometimes called a sea of plastics because it covers almost 50,000 acres (200km<sup>2</sup>). Crops grown in the greenhouses include: flowers, tobacco plants, herbs, vegetables and fruits such as tomatoes, peppers, cucumbers and melons which are in very high demand in the continent. British Columbia's high technology greenhouse vegetable industry is a highly successful sector of horticulture (Harjunowibowo, Cuce, Omer & Riffat 2016). They are recognized as the world leaders in utilizing advanced technology in biological pest control and computerized climate control systems. An ideal growing environment and reduced pesticide use allow for the production of high-valued fresh market crops. The industry also benefits from being highly organized in areas of marketing, production, research and industry development.

Worldwide, the main greenhouse vegetable production areas include Spain, the Netherlands, Mexico, Canada and the United States. Production in Spain and Mexico consists of variety of production systems ranging from low to high technology greenhouses. Production in Canada, Netherlands, and United States consists primarily of high technology greenhouses with significantly higher yields (Harjunowibowo, Cuce, Omer & Riffat 2016).

British Columbia has benefited significantly from being forerunners of meeting consumer demand and adapting to modern greenhouse technology. Lately the industry has been challenged by lower prices, high energy and transportation costs, and increased competition. Greenhouse vegetable products are becoming a commodity after many years of being perceived as higher priced niche market products. Growth of British Columbia's greenhouse vegetable industry is expected to continue at a slower pace, but will be influenced by many factors. Overall supply and demand, and cost control especially of energy, labour, marketing and freight, will be major factors (Resh 2016).

Greenhouse Production trends may include emphasis on food safety protocol new plant varieties and production systems that offer more efficient use of inputs, and new technology in the areas of gutter systems, re-circulated irrigation, supplemental lighting and cogeneration energy systems Other industry development opportunities being explored are in new crops that may have a niche market potential. These include strawberries, raspberries, eggplant, hot peppers, sugar peas, Snap beans, wasabi, watercress, Chinese vegetable, culinary herbs, and medicinal purposes (Resh 2016).

According to National Geographic production on Netherlands is termed as the 'world giant in agriculture' due to its extensive innovation in greenhouse farming (Wicaksono, Jeong & Kang 2017). Netherlands is known as world leading producer of cut flowers. Kenya has also adopted use of greenhouse whereby schools, churches and individuals have made use of the technology by increasing food crop production. Food self-sufficiency refers to the extent to which a region or country can satisfy its food needs from its own domestic production rather than rely on international markets. Food security is the access by all people at all times to enough food for an active, healthy life. Food insecurity is the lack of access to enough food. Food insecurity can be experienced worldwide, countrywide, regionally or in a specific county (Connolly 2018).

Ikutha farmers have been faced by famine due to lack of enough rainfall leading to food insecurity and food self-insufficient and thus starvation both to animals and human beings even some have gone to an extend of eating domestic pets like dogs and wild fruits which are poisonous. These farmers have low purchasing power thus the food crops from other counties are very expensive for them to buy. Though Ikutha farmers are able to produce more food which will suffice their future food needs and either sell the surplus to earn them income, they do not have the capability to expand their production hence food insufficient continue to haunt them day in day out (Omoyo, Wakhungu & Oteng'i 2015).

According to a report by Ikutha Sub-county Agricultural Office, Dorcas international Aid (DIA), a Faith Based Organisation started greenhouse technology in 2009 at Ikutha. Ministry of agriculture, County Government of Kitui together with catholic diocese followed suits by donating more greenhouses. Crops which were grown under greenhouse by then included tomatoes, kales, capsicums, spinach, and onions, cowpeas, chilli, maize, passion fruits among others. Other Non-governmental Organizations for example Red Cross, World Vision, Child Care International, ADRA, SASOL Foundation and Samaritan Purse have donated agricultural inputs and equipped Ikutha farmers with farming skills. They have also trained Ikutha farmers on how to use greenhouse technology. These organizations have donated relief food to Ikutha community (Omoyo, Wakhungu & Oteng'i 2015).

## **1.2 Statement of the Problem**

Mutune and Maingi (2017) argue that most of the residents in Ikutha Sub-county have faced food insecurity for a long period due to unreliable rains and seasonal droughts. Farmers are left with few options to get food when rains fail and animals die due to draught Food insecurity is high with over half of the population not being able to have foods of their own choice for all the three meals in a day. The situation has forced many of the farmers along the rivers to increase their food security. Only few farmers are able to invest in greenhouse farming as it is expensive and not all farmers can get access to water supply to support greenhouse farming. Ikutha farmers have been food insecure over the past years due to the marginal nature of the area (ASAL) which is characterized by inadequate rainfall or no rainfall at all (Anuga & Gordon 2016). The residents buy food from neighboring counties at high cost and those who cannot afford rely on relief food provided by Government, Non-Governmental Organizations (NGOs) or Faith Based Organizations (Adventist Development and Relief Agency, 2007). Government has been providing Ikutha farmers with agricultural inputs such as seeds for instance in 2006, they were given maize seeds and they risked their life by cooking the seeds after washing off the chemical preservative (Ikutha Sub-county Agricultural report, 2006).

In January 2009 the Government of Kenya declared a national food security emergency and declared an estimated total 10 million people at risk. NGOs and FBOs such as, Adventist Development and Relief Agency, SASOL Foundation, Dorcas International Aid (DIA), AMREF, Child Care International, Red Cross, GOAL (Global livelihoods' agency) and Samaritan purse



have come up to assist Ikutha residents by providing them with food, farming skills and farming inputs (Anuga & Gordon 2016). The many NGOs have stepped in to aid in alleviating food insecurity through providing skills, agricultural inputs and supporting farmers in various ways including marketing of their produce when there is bumper harvest, a rare situation in Ikutha Sub-county. The Ikutha Sub-county is an ASAL area and prone to food insecurity. Other factors that have resulted to high food insecurity include lack of awareness of farmers on approaches they can use to increase their food diversification and new improved approaches to improve farming. Farming attitude has also led to increased food insecurity as many young-abled persons rush to the cities in search of jobs leading to reduced food security among the local Ikutha sub-county farmers.

Dorcas International Aid (DIA) introduced greenhouse technology in Ikutha area in 2009. The greenhouse technology was adopted by farming groups of youth, women, and individuals who felt they had the capacity and skills for crop production (Mutune & Maingi 2017). Although more than 200 farmers were given greenhouses by NGOs to farm, majority never used them due to group wrangles, lack of water, maintenance costs and installation costs. The farmers had to incur a higher costs of customizing the donated greenhouses. This involved fixing netted structure at the bottom of the greenhouse to regulate temperature in the greenhouse, given the high temperatures Ikutha area experiences. Farmers found it hard to work in these greenhouse due to extreme heat inside the greenhouses.

According to Ikutha Sub-county Agricultural Office, some of the donated greenhouses were taken back by the donating bodies and the ones that were never used are in a deteriorated state (Mutune & Maingi 2017). Even with these challenges, there are organizations both Government and Non-government who still donate greenhouses to farmers. Will this farming technology solve the issue of food insecurity in this area? Opportunities may emerge to support food security programs for smallholder farmers, as the agriculture sector is increasingly considered a means of reducing poverty. Currently, there are approximately 200 farmers who have adopted greenhouse farming at Ikutha area. These farmers grow vegetables such as kales (*sukuma wiki*), tomatoes, spinach, onions, passion fruits, maize, cowpeas, coriander, and among others.

According to Mutune and Maingi (2017) there is a strong link between drought, food insecurity and food self-insufficient. These have contributed to high levels of poverty, malnutrition, illnesses and general economic hardships related to the drought phenomenon in this region. Since the introduction of greenhouse technology, no research has been conducted in Ikutha area to evaluate the effects of the technology in solving food insecurity problem. This research gap was the motivation behind the study to focus on this key area in managing food security within the ASALs (Mutune & Maingi, 2017).—The purpose of this study was to assess whether the introduction of greenhouse technology has led to food security at Ikutha area, Kitui County.

### **1.3 Objectives of the Study**

#### **1.3.1 General Objective**

To assess the effects of greenhouse technology on food security at Ikutha sub-county.

#### **1.3.2 Specific Objective**

- i. To assess the status of food security in Ikutha sub-county
- ii. To assess the productivity before and after the greenhouse adoption
- iii. To assess the income of the farming groups before and after greenhouse adoption.
- iv. Identify challenges faced by the farmers after greenhouse adoption.
- v. To make recommendations for addressing the challenges.

### **1.4 Research Questions**

- i. To assess the status of food security in Ikutha sub-county
- ii. How much yields have the farmers been getting before and after greenhouse adoption?
- iii. How much income have the farming groups been generating before and after greenhouse adoption?
- iv. What are the challenges facing greenhouse adoption in the area?
- v. What recommendations can aid in the greenhouse adoption that leads to increased food security in this area?

## **1.5 Hypothesis**

H<sub>0</sub>: There was no significant difference in yields for farmers before greenhouse adoption and after greenhouse adoption

H<sub>1</sub>: There is significant difference between yields for farmers before greenhouse adoption and adoption of greenhouse farmers.

H<sub>0</sub>: There was no significant difference in income earned from farm produce before greenhouse adoption and after greenhouse adoption

H<sub>1</sub>: There is significant difference income earned from farm produce before greenhouse adoption and adoption of greenhouse farmers.

## **1.6 Justification of the study**

This study sought to generate useful insights that may be used by the government, Non-governmental organization, Faith based organizations and farmers to promote viable alternative source of food production, creation of employment and generation of income in this area. This study is important in that it delved in the adoption of sustainable methods of farming that can help in ensuring there is continuous production of food throughout the year. This ensures food security to the residents of the study area.

Due to low purchasing power, Ikutha residents cannot access food needs and thus they need capacity to be food self-sufficient and food secure. Introduction of greenhouses will help them generate income because they will be harvesting crops all year round thus they will sell the surplus. This will cause malnutrition and hunger to cease. This will stimulate regional development thus services that are lacking in this area like health care services and microfinance will come up. Farmers will get varieties of crops because they can plant any time of the year. Research institution for example Kenya Agricultural and Livestock Research Organisation (KALRO) can carry out their research in these greenhouses and their results if helpful can benefit these farmers, also agribusiness people can benefit if they produce quality crops then they can export to earn them foreign exchange that is revenue to the nation. The money used to buy relief food by the national government can be channelled to other sectors of the economy leading to development in the country.

This study also sought to offer useful recommendations to aid in the realization of the Kenya vision 2030 as well as the Millennium Development Goals (MDGs). The study will also be useful to policy-makers and planners. For policy-makers, the study will help in the understanding of various ways in which they can support agricultural initiatives in the country for the realization of food security. It will guide them on the best way for handling the issues related to food insecurity. Besides, the policy-makers can learn from the study, the best alternatives to take to ensure food security in the country, and understand the areas where there is need for further investment.

On the other hand, the study will be useful to planners, as it will offer them the direction they need for developing a comprehensive plan to meet the food needs of the society. It will also be useful to learners considering that it will help them identify various areas that are suitable for greenhouse agriculture. Mutune and Maingi (2017) found out that there was significant association between embracing climate-smart agriculture and food production, an aspect that also influenced food security. The study was chosen since Ikutha sub-County falls under ASAL area and thus the study being conducted in Ikutha could confirm whether embracing greenhouse farming could improve productivity and income among the farmers.

The reason for choosing the study area is that there has been an influx of Non-Governmental Organizations in the area, who come in the name of equipping the local community to be food secure. They further introduce greenhouse technology in the community and equip Ikutha residents with greenhouse farming skills. In addition, they donate relief food to these residents. So, the study was assessing whether Ikutha Community have been food secure through adoption of the new technology. This was achieved through assessing the changes of their income and food production over a period of five years after adoption of greenhouse.

### **1.7 Assumptions of the Study**

The study had adopted some assumptions to enable the findings to hold. The study assumed that productivity changes before and after greenhouse adoption was influenced by greenhouse installation. There are other possible reasons that could influence the changes in productivity like application of fertilizer, spacing, planting different variety of the same crop, and changes in amount of rainfall especially before greenhouse farming. The study assumed that farmers planted the same variety of crop on the same size of parcel of land and that other factors likely to influence

productivity were held constant. The increased incomes were associated with increased productivity assuming that previously the farmers had sold their farm produce, and were able to compare and remember prices and income earned from selling the produce. The increased production was also assumed to be associated with improved agricultural greenhouse farming.

### **1.8 Scope and limitations of the study**

The study focused on those residents who have adopted greenhouse technology. Income changes and change in food production before and after greenhouse adoption was the focus of the study. This was to seek any relationship between these two variables, that is, income (independent variable) and food production (dependent variable) changes to those who have adopted greenhouse technology. It mainly focused on a four year production period.

The study also delved on the challenges farmers experiences while using greenhouse technology. The main method of data collection used in this study was the use of questionnaires. Majority of farmers do not keep records of their farm produce. Some of the respondents faced difficulties recalling their yields and prices of their farm produce given that data was to be extracted from past years. Hence, findings may be facing the limitation of memory lapses.

Ikutha area has vast lands and the researcher had to travel long distances from one respondents to another incurring high transports costs. The roads were murrum and the only means of transport was a motorbike making it expensive to the researcher to hire more motorbikes for each enumerator.

### **1.9 Definition of significant terms as used in the study**

**Food self-sufficient-** The extent to which a country can satisfy its food needs from its own domestic production.

**Food security-** Access of all people at all times to enough food for an active, healthy life.

**Food insecurity-** A situation that exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life.

**Greenhouse-** A structure with walls and roof made mainly of transparent material, such as glass, in which plants requiring regulated climatic conditions are grown.

**Farmer-**A person in charge of greenhouse farming where crops are grown under regulated climatic conditions.

### **Climate change;**

Climate change is change in global or regional climate patterns, in particular, change apparent from the mid to late 20<sup>th</sup> century onwards and attributed largely to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels (Lal, Stewart & Uphoff, 2005) Climate change has led to global warming which is the increase in global average temperatures. The change is being attributed to natural factors for example volcanic eruptions, Changes in earth's orbit and energy from the sun. The other factors are anthropogenic factors and include burning of fossil fuels, coal, oil and gas, destruction of forests among others. The burning of fossil fuels increases heat trapping gases in the atmosphere, for example carbon dioxide which are called greenhouse gases (C.H.D. Magadza, 2000).

### **Concept of green house**

In order to curb the food shortage and get away with natural environment which is harsh for open field grown crops ,researchers have come up with greenhouse which is a structure with walls and roof made of transparent material, such as glass, in which crops requiring regulated climatic conditions are grown. Greenhouse can also be called glasshouse or hothouse. These structures range in size from small sheds to industrial-sized buildings. A miniature greenhouse is known as a cold frame.

Since greenhouses use the sun to create a warm environment for plants, when the temperature drops, there is less -generated heat by sun in the greenhouse. For plants that need more heat than a greenhouse can provide naturally, heating systems are necessary to make up the difference. Greenhouses are divided into categories based on how much supplemental heat they need to produce in order to keep plants at a certain temperature.

There are different types of greenhouses as highlighted by Cuce, Harjunowibowo and Cuce (2017) that depends on agro-ecological zones they will be used. These include;

**Cold Houses and Cold Frames:** Cold houses provide protection for plants, but the temperatures inside can still drop below freezing during the winter because they have no supplemental heat source. Cold houses can help start spring crops a few weeks early and extend the growing season in fall weather limits them.

**Cool Houses:** Warmer than cold houses, cool houses keep plants above freezing and in a temperature range of between 45 to 50 degrees Fahrenheit (7 to 10 degrees Celsius) Keeping the temperature above freezing will protect **frost sensitive** plants which would be impossible to keep year round in areas that experience freezing temperatures.

**Warm Houses:** A warm house will allow a broader range of plants, but requires slightly warmer temperatures too, around 55 degrees Fahrenheit (13 degrees Celsius). Although the temperature range doesn't support many tropical plants, some varieties can over-winter in a warm house environment like orchids and ferns

**Hot Houses:** These greenhouses are designed to house **tropical plants**, which need a temperature range of 60 degrees Fahrenheit (15.5 degrees Celsius) and higher. They require the most supplemental heat and insulation and can be expensive to maintain.

**Conservatories:** Conservatories are designed to display plants, not just maintain and propagate them. They often have finished floors, ornate window treatments and space for furniture. Window greenhouses and small table top greenhouses are also considered conservatories because they're used primarily for display.

## **CHAPTER TWO: LITERATURE REVIEW**

### **2.1 Introduction**

Chapter two introduces theoretical and empirical review related to food security, greenhouse technology, changes in food production and consequently changes in income as influenced by adopting new agricultural technology. The chapter also presents the conceptual framework and the research gaps identified in the study.

### **2.2 Empirical Literature Review**

This section presented the empirical literature review covering the four objectives of the study. The literature review focuses on climate change, changes in productivity and income as realized from adopting greenhouse farming technology.

#### **2.2.1 Climate Change and Food Security**

Climate change has made it unfavourable to produce crops on natural environment and this has resulted to invention of technologies to create an environment which is conducive for crops to grow by regulating the conditions that crops require for growth and development. Greenhouse has been one of the many technologies to combat effects of climate change (Phillips, Magos Brehm, van Oort, 2017). Globally, countries are advocating to promote sustainable consumption and production patterns through strengthening developing countries' scientific and technological capacities. This is calling for adoption of technologies, which are environmentally friendly. Global population has been rising and the available limited resources experience pressure to produce for the growing population. This has led to environmental degradation and conflicts over natural resources (FAO, IFAD and WFP, 2014).

Climate has never been constant and its effects have been experienced in many sectors of the economy (National Research Council, 2000). These sectors include fishing, agriculture, wildlife, forests, water bodies, loss of biodiversity among others. The average annual temperature has risen to 0.6 degrees Celsius brought about by the onset and retreat of the ice changes. Sometimes we have hotter summers than average and some winters wetter than others do and windier than others. The reason for such variations is not always predictable. Considering that food is one of the basic elements that support the psychological needs of individuals, it is clear that it supports humans.



Globally, countries are advocating to promote sustainable consumption and production patterns through strengthening developing countries' scientific and technological capacities. This is calling for adoption of technologies, which are environmentally friendly. Global population has been rising and the available limited resources experience pressure to produce for the growing population. This has led to environmental degradation and conflicts over natural resources (FAO, IFAD and WFP, 2014).

Water shortage has also contributed to decreased food production globally and it is expected that by 2025, 52 countries may face water shortage affecting 3 billion people (Alcamo, Henrichs & Rosch 2017). This has been due to pollution on water bodies by industrial effluents and sewage wastes being channelled to oceans, rivers, and lakes among other sources. This waste has chemicals interfering with water quality and physical composition of water. This water when polluted becomes unfit for consumption and agricultural production. Biodiversity has been lost because some crop species cannot survive in the current conditions of climate (Alcamo, Henrichs & Rosch 2017). Global warming which is brought about by climate change has led to reductions in average crop production. Inadequate rainfall in those areas that received adequate rainfall is experiencing little or no rainfall at all. This has led to food insecurity, malnutrition and underdevelopment in those regions.

According to Cianfrani, Broennimann, Loy, and Guisan (2018) national parks and/or protected areas being the habitat of wildlife have been negatively affected by global warming. This has led to starvation of wildlife. Water shortage has also affected wildlife procreation. Increased population is also threatening wildlife by poaching them for food or for economic use. Some animal species have become extinct. Food for these animals is barely growing and some plants, which were food for wildlife, have become extinct. The atmosphere generally has been polluted (Cianfrani, Broennimann, Loy, and Guisan, 2018). Air has been polluted by industrial emissions releasing harmful gases to the atmosphere that deplete the ozone layer. The ozone depletion has led to complications on humans including eye damage, skin cancer and breathing problems among others

The melting of glaciers, snow, aquifer's, and ice caps has led to increase in water in seas, oceans which has led to flooding and sea level rise by 1-2mm per year in the last 100 years. An annual average temperature change globally has led to EL-Nino, which has caused ocean currents to

reverse (turn back) (Wicaksono et al., 2017). Generally, there has been shortage of water globally. Housing collections of plants from around the world, the Eden project, the largest green house project, is a series of futuristic domes nestled in a converted clay quarry.

### **2.2.2 Impact of the size of greenhouse on food security**

The invention of greenhouse was due to the demands to produce better quality and a higher economic value crops. The invention has also been greatly steered by the unfavourable climatic conditions that at natural conditions some crops cannot grow all year round. This is brought about by inadequate rainfall, high or low humidity, among other climatic conditions. Due to these demands, many farmers use the technology of greenhouses to produce their agricultural goods (Lal, *et al.*, 2005). This technology has led to increase of income to both commercial and subsistence farmers. The large-scale farmers are able to sell their crops. This has led to majority of farmers focusing entirely on greenhouse farming. The cost of production for a large-scale farmer is not expensive such that it is accessible and pocket friendly for any ordinary farmer who would like to venture on this technology.

Greenhouses can exist in three types namely; single greenhouses, freestanding, and gutter-connected bays. The gutter-connected formation is more economical when considering building more than one greenhouse (Turrall et al., 2011). For tomatoes, the typical length of greenhouses is 96 feet by 130 feet since there is a possibility of finding plastic covering at 100-foot length. The length is the longest practical one considering the distance required between the vent and the exhaust fan needed for cooling. On the other hand, a greenhouse longer than 150 feet will have too much temperature gradient between the intake end and the exhaust end. Larger greenhouses lead to an increase in food production that further leads to the enhancement of food security (Turrall, Burke, and Faurès, 2011). In addition to greenhouse adoption, farmers have also adopted other farming technologies. These adoptions may include;

### **2.2.3 Genetic engineering cultivars**

Researchers have come up with genetically engineered cultivars that can withstand the harsh climatic conditions. The genetically modified foods are of good quality, mature early and their morphological compositions have been made better compared to the non-artificial ones. For example, tomatoes are of a big size. Crops, which are pest resistant and disease resistant, have also been invented and this has led to food increase (Thornton, & Herrero, 2015).

There have also been improved methods on pests and disease prevention and control. Genetic engineering technologies, such as CRISPR genome editing, make it possible to easily modify living organisms in specific ways (Thornton, & Herrero, 2015). This could be used to create superior strains of crops which produce greater yields and more blight resistance. Today, most of the world only relies on a handful of crops—corn, rice, and wheat, mostly. If a blight were to wipe out one of these, it would be a serious problem for humanity. The ability to use genetic engineering to breed disease and pest resistance into staple crops and make different crops commercially useful is, thus, another safeguard against such a disaster.

#### **2.2.4 Remote Sensing and Agricultural Robots**

As satellites become more easy to use, it is more common for them to be used by businesses and private individuals to accomplish their tasks (Resh, 2016). Agriculture is no different. In India, for example, remote sensing is being used to monitor crops and crop damage. This will make damage to crops easier to maintain. This is also being used by insurance companies to better assess insurance claims by farmers to cover crop damage. This could also be used to monitor the productivity of different farm areas and find solutions more quickly.

Automation has enormous potential to transform agriculture. The use of robots to plant, reap, and process grains would make the process more efficient and easier to perform on the scale required to feed the world's growing population (Satterthwaite et al., 2020). Robots could also be used to monitor plant growth and the health of the crops. There are proposals to use micro-robots for this purpose, to swarm fields to monitor the crops. Tractors, drying seeds/cereals machines, harvesting machines and transporting machines have been invented. Use of tractors has led to increase in food production for both small scale and large-scale production. Wheat harvesting is now being done by machines reducing labour costs and shortening the time of harvesting (Thornton, & Herrero, 2015). This has led to the reduction of post-harvest losses. Coolants/freezers are being used to preserve food crops, which are highly perishable, for example flowers, vegetables among others.

The use of drones in agriculture has already begun and, in 2018, it will only increase. Drones can be used for a variety of purposes in agriculture that lower costs and increase potential crop yields. One use of drones in agriculture is for soil analysis since they can create high-quality 3-D images of the soil to determine the nutrients in the soil and how conducive it is to crop growth. They can also be used for planting, crop spraying, and crop monitoring; for example, monitoring the health

of crops and any fungal growths or infections which may hinder their development. Drones can even be used in irrigation since they can assess fields and determine which parts of a field are particularly dry and need more water (Resh, 2016). It is possible that, in the future, swarms of drones will descend upon agriculture fields, performing various surveillance tasks.

### **2.2.5 Productivity in greenhouse adoption**

Canakci, Emekli, Bilgin, and Caglayan (2013), in their study, highlighted that the protection that crops grown in the greenhouse get against diseases, pests, and other hazards allow them to produce more yields compared to open field agriculture. Further, the authors note that the closed nature of greenhouses reduces the risk of soil borne diseases, especially those that affect tomatoes. Therefore, through reducing the incidences of crops being attacked by diseases and pests, greenhouse farming leads to an increase in yields as compared to open farming. Koivisto and van der Vlist (2011) highlight that in the case of cucumber growth in the Finnish industry. The new-energy intensive technology under greenhouse farming led to an increase in the net cash flows and the yields received. However, the authors warn that the result is better for ineffective large firms compared to small firms. Cook and Calvin (2005) notes that greenhouse farming has led to positive results in North America in regards to the farming of tomatoes, with Mexico being a good example. Tomatoes are delicate crops that require absolute care. The authors highlight that before the adoption of greenhouse technology, tomato yields in Mexico were short because of the infections that affected their leaves caused by splashes of rain. However, the introduction of greenhouses led to the shift in productivity, with the farmers in the country experiencing high yields (Pariyar et al., 2016). Greenhouse farming uses drip form of irrigation that allows the crops to receive the amount of water they need for growth, which further reduces fungal tomato diseases that normally thrive in wet foliage.

The introduction of greenhouse technology in the farming of tomatoes has seen a two-fold increase in the yields of the crop in Mexico, which is a great indication of the importance of the technology in improving yields (Cook and Calvin, 2005). Heforth (2010) notes that Africa has been a major beneficiary of greenhouse technology, as it have positively affected the yields received by farmers in the continent. Herforth (2010) highlights that weeds are a major challenge to farmers in Africa, especially those engaged in open agriculture. Greenhouses reduce incidences of weeds, making it easier for African farmers to increase their yields. The author even highlights that since the

adoption of greenhouses, the continent has seen a major improvement in agricultural yields (Herforth, 2010). Therefore, from the studies highlighted, it is clear that greenhouse technology has led to major improvements in the yields received by farmers across the world, with evidence being present in North America, Africa, and Europe.

#### **2.2.6 Effects of greenhouse adoption on income level**

Even though the adoption of greenhouse technology can be costly to consumers, the adoption of greenhouse technology leads to positive results on the income level of farmers. Satterthwaite, McGranahan, and Tacoli (2010) underline in their study that greenhouse farming reduces incidences of theft, which in turn, allows the farmers to receive maximum yields for their produce. In their study, the researchers questioned farmers on the benefits of greenhouse adaptation, with 75% of them responding that it helped them curb the issue of theft they experienced while practicing conventional agriculture (Satterthwaite, McGranahan, & Tacoli, 2010). Brown and Miller (2008) support the assertion that greenhouse technology has a positive impact on the income levels of farmers. In their study, one of their major findings was that 52% of the farmers interviewed reported that they have realized high yields that have translated into good returns since they adopted greenhouse technology. Therefore, from the evidence presented by the two researchers, it is clear that greenhouse farming has been positive to the increase in income level of farmers.

#### **2.2.7 Adoption of greenhouse technology in Kenya**

Greenhouse has been used in Kenya for example by Amiran. Amiran Kenya Ltd, the leading agro inputs supplier in Kenya together with African Boreholes Initiative, has brought a first of their kind innovation to the small-scale farmers of Africa ushering them into the world of organic farming (Pariyar et al., 2016). The newly introduced technology aims at causing environmental and food security changes in Kenya and Africa as a whole. The Youth Enterprise Development Fund (YEDF) and Amiran Kenya Ltd have partnered to support young farmers in acquiring a tailor made Amiran Farmers Kit (AFK) designed specifically for the AgriVijana Loan. YEDF has started the AgriVijana Loan to help youth, who are in groups, to get involved in Agribusiness by purchasing the special AFK's each with 2 greenhouses and a large irrigated area.

The Amiran Farmer's Kit (AFK) was created with the aim of allowing small scale farmers affordable access to modern agricultural technologies, methods and inputs of the highest standard. Designed by Amiran Kenya Ltd, the AFK is a tailor made Kit designed to meet the needs of the specific farmer or group of farmers by adapting the components of the Kit to suit the climate, terrain, and agricultural experience of the farmer. The AFK comes complete with installation, training and an agro-support package that would allow Amiran to teach the “Amiran Farmer” how to grow and then stay with the greenhouse.

Article 43 of the Constitution of Kenya, 2010 gives right to every Kenyan citizen to be free from hunger. Therefore, it is important for Kenyan government to adopt technologies such as greenhouse technology to boost food productivity. Kenya is one of those countries, which have been affected by global warming. There has been cases of famine, floods, drought, and increased levels of poverty and death of livestock in Kenya.

#### **2.2.8 Adoption of greenhouse technology in Ikutha**

Ikutha division being an ASAL region has been threatened by starvation, illnesses and stunted growth and development. Drought has contributed greatly to stagnant development in this area, the residents are malnutrition and also lack of health care services has contributed to slow growth (Mutune, & Maingi, 2017). Farmers in this area cannot do other farming activities for example livestock keeping and bee keeping this because drought has almost wiped out livestock bringing the lives of people in a near halt. This area is marginalized in many aspects such as in development, economically, and in education particularly primary and secondary education.

Higher yields come along with the use of new technology which is accessible to the targeted group which makes them improve their standard of living and be food self-sufficient. Drought in this area is severe having experienced its effects. Drought can be defined as a period of dry weather, a long period of extremely dry weather when there is no enough rainfall for the successful growth of crops or the replenishment of water supplies (Mutune, & Maingi, 2017). Meteorological drought is all about the weather and occurs when there is a prolonged period of below average precipitation, which creates a natural shortage of available weather. Agricultural drought occurs when there is not enough moisture to support average grass production on rangeland or average crop production on farms. Although it often occurs during dry, hot periods of low precipitation, it can also occur

during periods of average precipitation when the soil conditions or agricultural techniques require extra water.

Hydrological drought occurs when water reserves in aquifers, lakes and reservoirs fall below an established statistical average. It can also happen even during periods of average or above average precipitation, if human demand for water is high and increased usage has lowered the water reserves. Implications of drought on agricultural production at Ikutha; economic impact Ikutha residents have to buy food at high prices from other counties. Almost every penny is channelled to buying food leading to slow growth in other sectors for example in education and health care. Regional development is sluggish in this area because no more savings to be used in development this is due to low purchasing power (Omoyo et al., 2015).

Political impact-mistrust and lack of confidence starts to prevail among government officials for example, chief officers fail to deliver all the relief food to their people and instead sell it (Marshall, 2014). Health impact due to low purchasing power of farmers means they cannot access health services like dispensaries and hospitals leading to illnesses, malnutrition and high mortality rate among children.

### **2.2.9 Challenges in adoption of greenhouse technology in Kenya**

The *Seeds of Gold Magazine* stated that farmers fail to get good profits from greenhouse crops because they cannot manage the two important factors that determine plant growth and productivity (Omoyo et al., 2015). Greenhouse temperatures below 13 degrees Celsius and above 30 degrees Celsius in the case of dry air or higher than 30 to 35 degrees Celsius in cases of high air humidity affect growth and productivity of most crops (Kimanthi & Hebinck 2018). Management of insect pests and diseases is the biggest challenge in greenhouse farming. This depends on the type of the crops that are planted. However, generally, pathogens and insects can be established in a greenhouse very fast. They are very difficult if not impossible to get rid of effectively (Kimanthi & Hebinck 2018).

Many parts of Kenya are deficient of good water sources and rivers or boreholes may also be absent. In addition, available water could be saline, chlorinated or contaminated with diseases like bacterial wilt, hence it is of poor quality. Contaminated water is common in areas where farmers

in sources of water plant crops like potatoes, tomatoes and water flowing downstream is collected by farmers for greenhouse farming. This introduces bacterial wilt in greenhouse tomato.

Loss of fertility is a common problem as most farmers plant one crop continuously without rotation. The soils when used continuously with same crop will have a buildup of diseases, especially bacterial wilt, bacterial canker, fusarium and verticilium wilts. Greenhouses get contaminated by people visiting the structures or by use of infected planting material, water and farm tools (Omoyo et al., 2015). Greenhouse structures require more resources to maintain compared to open farms. For example, you need to protect greenhouses from low temperatures and strong winds through insulation. Even though open- field farms demand high control of pests and weeds, this can be carried out through mechanical methods. The farmer's trend (2017) magazine mentions that professional knowledge and skills is needed in greenhouse farming to aid in regulating its environment. In the event the farmer does not have the required skills, this could result into an extra cost through hiring qualified personnel. Nonetheless, greenhouse farming is the best option in areas that have harsh climatic conditions, which do not favor normal open field farming.

Kimanthi and Hebinck (2018) mentioned that there is also high upfront and operating expenses needed. In order to utilize a greenhouse to the best of its ability, you will need to invest in a kit or supplies that will have a good lifespan and proper characteristics for the plants you want to grow. For example, cheaper film plastics may provide sufficient conditions to retain heat, but more expensive glass windows will last longer and may help ventilate the greenhouse if able to be opened. With maximum climate control, comes the potential for a very high operating cost. In case you use electronic heaters or by way of gas, there will be increase in your energy bill.

### **2.3 Theoretical Framework-(The Diffusion of Agricultural Innovation Theory)**

The study adopted the diffusion of agricultural innovation theory to act as the core pillar or rather provide an overall framework for the analysis of the linkages on food security. The diffusion of innovation theory was conceptualized and advanced in agriculture by Everett M. Rodgers through his doctoral dissertation in 1957. The analysis was through how technology was diffused into the society to influence changes. Rodgers believed that innovations flow in a universal process associated with social changes. The diffusion of innovation theory follows five stages where of



starts with innovators (about 2.5% of the population), then moves to early adopters (13.5%), then to early majority (34%), then late majority (34%) and laggards (16%) at the end of the diffusion of innovation. The diffusion of innovation theory has four elements that explain the key concepts that help farmers benefit from the theory. They include an idea or innovation, communication channels, the time involved to diffuse the theory and the social systems engaged to diffuse the theory. Godfray et al. (2010) defined innovation as the introduction of a new concept or idea on doing a particular activity that has been done in the past in a different way. The researchers introduced the concept of “new combinations” to describe the process of making effective use of combinations between the new and the old technologies, which later helps in the uncovering of the most conducive new fields of application. Some of the forms of innovation that the researchers give include completely new products, new production processes, and new sources of supply and markets.

Porter et al. (2014) presented a different understanding of the concept of innovation, as they rather described it as a process whereby organizations master and implement the design and production of goods that they consider new to their knowledge base, irrespective of whether they are new to particular individuals or the whole world. Thus, innovation encompasses a lot of elements that include the large and small improvements in areas such as the design of the product, modifications in the process of production, and adoption of techniques that collectively aim at reducing the cost of production. Innovation also aims at improving the efficiency of production, increasing human welfare, and ensuring that there is environmental sustainability as provided by greenhouse technology.

Understanding the degree of innovativeness is another way in which people can look at the nature of innovation. The studies concerning innovation, which are done in sub-Saharan Africa shows that most of the adopted innovation, have an incremental nature (Khan et al., 2014). The studies further highlight the rare nature of radical innovations in Africa. Incremental innovations are introduction of products, their services, and products that appear to be new to organizations, but not particularly new to the industry as a whole.

Khan et al. (2014) states that developing countries take a precautionary approach to innovation through adopting incremental innovation since it allows them to build on the innovation of other individuals. The resource poor environment where business failure can lead to devastating

financial consequences that can also lead to a potential effect on food security, are the areas where such precaution are key. Therefore, incremental innovation is an effective approach as it helps in the reduction of the risks involved in the innovation process. Greenhouse technology is a viable innovation that presents itself as a major step for enhancing food security in regards to the declining availability of land and water, climate changes, and the increase in urbanization that is experienced in Kenya and all over the world.

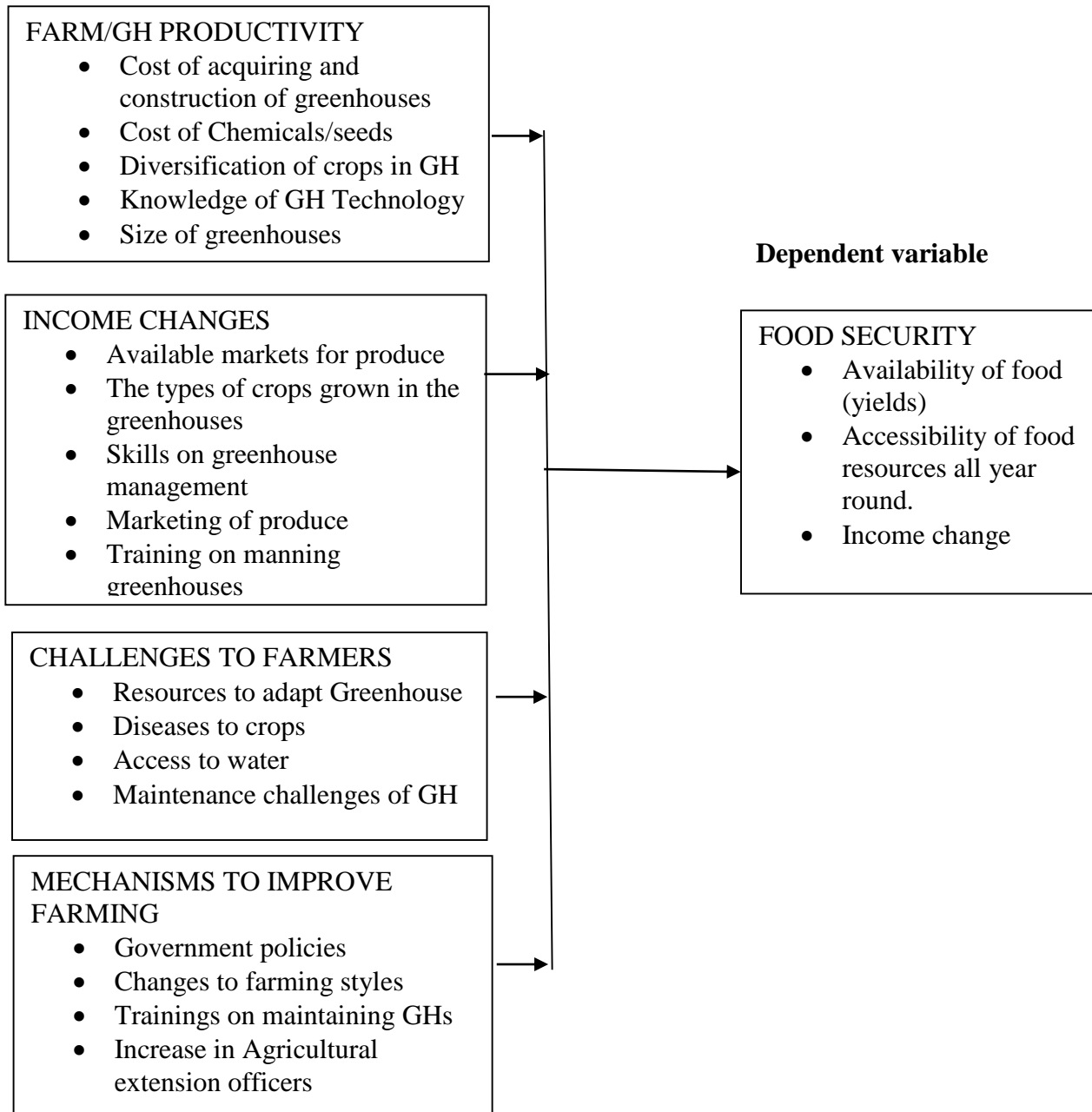
The study is based on diffusion of agricultural innovation theory where greenhouse farming has been used to improve production and increasing resilience among the farmers. The theory is relevant to the study in that it provides basis for adopting new technologies for production in agriculture. The theory addresses the way agricultural production and consequently the associated income can be increased through adopting new technology like greenhouse farming. The theory of innovation was best suited as it focuses on innovation and how it helps in making life better for people.

#### **2.4 Conceptual Framework**

The conceptual framework of the study was guided by the four independent variables that included farm/greenhouse productivity, income earned from the farms/greenhouses, challenges faced during farming, and mechanisms for improving farm productivity. The dependent variable was food security that was measured by the availability, accessibility of food and the income changes among the farmers.

The variables were measured through giving options to the respondents. Food security was measured by asking questions on practice of greenhouse, options of defining food security, and the frequency in which the households missed a meal over the last 12 months. Options for the cost of greenhouse were also presented allowing farmers to select the right options. Knowledge of greenhouse farming option was given options for the respondents to select the one best describing them. Yields harvested were measured by the amounts of kilograms from the farms and productivity was measured by the amount harvested per standardized unit, in this case an acre. Diversification was measured by the number of crops grown in a unit piece of land.

### Independent variables



**Figure 3.1: Conceptual Framework. Source: Author (2018)**

The independent variables have an influence on the dependent variable, food security. Cost of chemicals, seeds, structure of the greenhouses (purchase of) and the irrigation systems have an influence on how the size of farmland cultivated, and the harvest from the farm, influencing the number of kilograms per acre (productivity).

Knowledge of farming skills, skills on greenhouse management and marketing techniques also influence the production per acreage and income generated from the farmland. Knowledge of the farming skills and greenhouse management skills have an influence on food security through influencing availability, accessibility of food and the changes in income from harvested foods. Diversification of the crops is influenced by knowledge of farmers and the types of crops grown, that have an influence on income changes. The size of land and greenhouse size also influence the amount of food harvested and consequently the income earned.

The four independent variables were arrived at through establishing the agricultural practices and components that influence farm productivity as well as those that influence income from farmland. Cost influences productivity, as well as knowledge about farming technologies that enable farmers to have more income and productivity at their farms and homes.

## **2.5 Research gap**

Climate change has contributed to food insecurity globally. This has called for international committees to agree on how to eradicate food insecurity, which leads to malnutrition, hunger and diseases (Vermeulen, Grainger-Jones & Yao 2014). The international agreements have been advocating in adoption of a sustainable technology that takes care of future generations. This has called for green economy/blue economy. This has attracted agricultural technologies that have been adopted globally and succeeded by increasing food production (Phillips, MagosBrehm, van Oort, 2017). Few scholarly studies have been done on food insecurity in Ikutha region and especially on the engagement of greenhouse farming and its aspect of alleviating food insecurity. The lack of continuous data on how greenhouse farming and other technological approaches in agriculture can help in improving agriculture contributed to this study.

Researchers have come up with greenhouse technology, which uses the concept of atmospheric greenhouse effects. This technology has been successful in Columbia, Netherlands among other countries. Ikutha being an ASAL region has been facing inadequate rainfall thus residents facing hunger due to food shortage. This is because they entirely depend on rainfall for their crops growth and development. Organisations such as DIA and Catholic Diocese of Mutomo have introduced greenhouses to its residents by giving them the inputs and training for the use of this technology. Their aim is to increase food production and eliminate poverty by making the residents food secure.

This is because the greenhouse environment is regulated to suit a farmer's favourable conditions for his/her crops (Vermeulen, Grainger-Jones & Yao 2014). The research sought to assess whether the Government organisations, Faith-based organisations and Non-Governmental organisation's goals have been realized, that is whether introduction of the greenhouse has made people food secure.

From the review, the research gap identified was that there was lack of clear, regional and national and detailed longitudinal data concerning food security, its causes, and the coping strategies employed by the rural farmers, not only those in Ikutha region, Kitui County, but rather in Kenya as a unit (Mutune & Maingi 2017). Studies on the changes accrued in production and income after adopting new agricultural technologies are few, most of them focusing on high agricultural potential areas. Challenges and solutions have also been presented but for studies in other agricultural areas not necessarily ASAL regions of Kitui County. Thus, there was an identification of the need for collecting the ongoing reliable data, and synthesizing them for the increase in knowledge base and a better understanding of the aspects required for the enhancement of food security.

## **CHAPTER THREE: RESEARCH METHODOLOGY**

### **3.1 Introduction**

Chapter three focused on the approaches used to collect data and ensure data quality. The study design was explained in the chapter, as well as target population, sample size, data collection and data analysis. The study area was also described in this chapter.

### **3.2 Description of the study area**

#### **3.2.1 Geographical location**

Ikutha region is a semi-arid town located between Kitui and Kibwezi town. It is sparsely populated and dominated by the Kamba community. It has altitude of 2.0663400 and 38.1788500 longitudes.

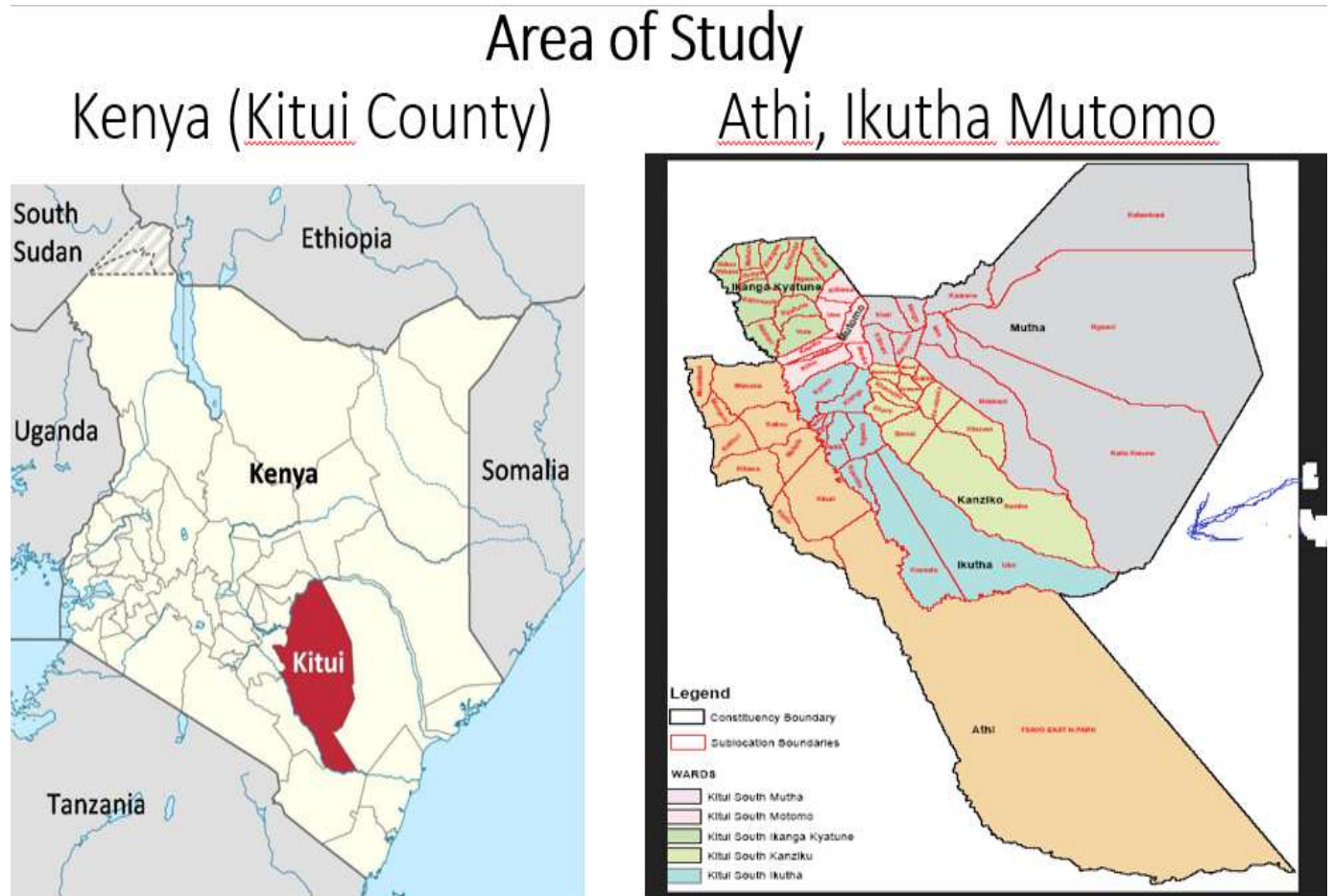
#### **3.2.2 Climatic and hydrological characteristics**

This part of Kenya forms an environmental gradient of decreasing altitude, increasing temperatures, and decreasing moisture. Ikutha residents report frequent crop failures and water shortages, and food relief has become a permanent feature. The ever-present need for food relief has been variously attributed to overpopulation and environmental degradation, to colonization and development, or to insufficient development.

The most significant changes in land use at regional scale have included a gradual shift from agro pastoral to mixed farming production systems, the continuing conversion of dry forest and savannahs to agriculture (Thornton & Herrero 2015). The progressive replacement of subsistence by commercial production from household to regional level, the "mining" of dry forest and savannah trees for commercial charcoal markets in the city, and the quarrying of sand from dry river-beds and channels to construct new housing and commercial buildings in the city.

The marginalized nature of the area has captured the interests of many organizations majority being Non-Governmental and Governmental ones. These organizations have been providing foods, seeds for planting and skills for farming to lift up the economic status of this region. Most of these residents are farmers.

### 3.2.3 Map of Ikutha within Kitui County in Kenya



**Source: Modified Kitui County Integrated development report**

The figure above shows Ikutha location, as contained in Kitui County in Kenya which was the study area.

### 3.3 Research design

The study used quantitative study design where data was collected using questionnaire. The research embraced a sample of respondents who were allowed to fill in the questionnaire. The researcher employed the survey design to collect and analyse data. The survey aided in digging up information on how adoption of the technology has been helpful and then comparing to the other times they were farming without the technology (open field system). Descriptive research determines and reports the way things are, and attempt to describe possible behaviour, attitude, values and characteristics of such things.

The quantitative research design was selected in this study because it allowed the researcher to gather numerical and descriptive data to assess the relationship between the variables.

### **3.4 Target population**

The study was undertaken in Ikutha area. The study focused on both small scale and large scale greenhouse farmers. According to the Agricultural Extension Officer based at Ikutha Ministry of Agriculture Office, there are approximately 200 farmers who practise greenhouse farming in Ikutha Sub-county. The target population was slightly 200 greenhouse farmers. The researcher considered the population relevant because being the most hit by drought and starvation due to low rainfall, would facilitate the establishment of facts on impacts of greenhouse adoption to food security.

### **3.5 Sample size and sampling techniques**

#### **3.5.1 Sample size**

There are slightly over 200 targeted greenhouse farmers at Ikutha Sub-county. However, the researcher restricted the study on a representative sample of 71 farmers. The reason for choosing the sample size of 71 is because of financial and logistical costs.

The sampled population of 71 persons was arrived at using the following procedure;

The formula adapted was suggested by as reported by Hossan-Chowdhury (2011).

The sample size was determined using the following procedure,

$$n = \frac{z^2 pq}{e^2}$$

n - Desired sample size *n* less than 10, 000)

z - Standard normal deviate at 1.96 corresponding to 95% confidence interval

P - Estimated proportion of target population (the greenhouses farmers within the

Ikutha region is taken to be 10% that gives us a workable sample size with the given level of significance and accuracy.

Q - I – p



$$\begin{aligned}
e &= 0.05 && \text{The error margin } 0.05 \\
n &= \frac{z^2 pq}{e^2} \\
n &= \frac{1.962 \times 0.1 \times 0.9}{0.0025} = 70.632 \\
&= 71 \text{ respondents}
\end{aligned}$$

The respondents were spread over three wards including Athi, Ikutha, and Mutomo. The respondents were spread over the three wards which also translate to sub-counties. The spread was based on the concentration of greenhouses where Ikutha and Athi sub-counties had more greenhouses compared to the other sub-county.

### **3.5.2 Sampling technique**

The people who formed the unit of analysis were farmers who were part of the sampling population. The study restricted on interviewing the farmers in the sample population because they are the ones with the information needed for the effective development of the research. Since the farmers were far placed from each other, and they were few over an expansive area, purposive sampling was used based on the information given by the area extension officers. Purposive sampling was used as it enabled the researcher to identify farms with greenhouses, explain to the farmer about the study, get their consent and engage the farmer in the study. The researcher identified the greenhouses after which the sample was identified. Purposive sampling was done as it enabled the researcher to focus on the available greenhouses amidst their few numbers in Ikutha region.

### **3.6. Data collection methods and procedures**

The data collection methods that was used in this study included questionnaires, observation, and documentary review. There was a review of various publications by the government, non-governmental organizations, research organizations, universities and international bodies. Secondary data on greenhouse farmers and factors influencing technology adoption were used as source of variables for analysis. Primary data were gathered from respondents by use of a questionnaire. The questionnaires were administered by enumerators after a pilot study. The data collected, especially for the crop yields and income was recall from the previous harvests and sales

from year 2010 to the year 2014. A challenge was experienced in recalling the amounts harvested and income gained but it was observed that some farmers had kept good records where they used the records to fill in the questionnaire.

Advance communication was effected by the researcher to all the parties who were informed of the intention to carry out the survey, the time and day, as well as the venue. These were the local administration staff and selected greenhouse farmers. The advance preparation likewise will involve a briefing to the parties as to the nature and purpose of the study.

### **3.6.1 Primary data**

#### **a. Questionnaires**

The researcher chose on this instrument as it captured a diversified sample and enabled the accomplishment of the survey in a limited time span.

#### **b. Observation**

The researcher used eyes to observe any happenings and made recordings on the same. This method provided undefiled first-hand information authenticated to the researcher.

### **3.6.2 Secondary Data**

Documentary review will inform the source of secondary data. Data was obtained from sources such as Government, Non-government organizations, Faith-based organizations and recorded information among others. It provided detailed information and statistics that could not be gathered from other sources.

### **3.7 Data reliability and validity**

For consistent results of the study, the researcher randomly selected few members to have a pilot study of the research tool so as to know where there exist loopholes for rectifications. This entailed even requesting the respondents to help in reframing a question or statement in a way that Ikutha resident will understand for accurate information.

The farmers who were doing pilot study did not participate in the main study. This was done to avoid alterations of answers by respondents now that they had a clue of what the study entailed.

### **3.8 Data Analysis**

Comparing of means for the farm income and yields before and after adoption of greenhouse was used, particularly the use of T-Test, paired sample t-test analysis. Statistical Program for Social Sciences (SPSS) was used in performing the paired sample t-test analysis to help accept or fail the set hypothesis. The T-test analysis was performed as it guided the study in providing platform for comparing the means of the data sets for production as well as data for income generated. In addition to T-test, other analysis like frequencies, mean, percentages and graphs were used to help explain data collected. T-test was best positioned better to offer comparison for the pre- and post-greenhouse adoption production and income generated from the crops grown pre-and post-greenhouse adoption.

The third and fourth specific objective was analysed by use of graphs, summarized tables and summaries of options given by the respondents to show the most and the least experienced challenge. This is because different farmers experienced different challenges. The two objectives were analysed through collecting views of the respondents, establishing the frequency of the responses, and summarizing the responses based on major themes. Thematic analysis was used for the two objectives where pen-ended questions were asked to the respondents.

The two null hypotheses were tested through comparing means of production before and after adoption of greenhouse farming, and also comparing means for income generated from agricultural produce, generated from two periods, pre- and post-greenhouse adoption. Once the means are compared, the null hypotheses will be tested on whether the production and income earned before and after adopting greenhouse farming were the same. If not the same, then it was then concluded that greenhouse farming had changed productivity and consequently the income earned. If  $p \text{ value} \leq \alpha$ , then the  $H_0$  was rejected. The  $p$ -value had to be less than 0.05 for the null hypothesis to be rejected and the alternative, that the means were not equal, to be accepted.

Excel computer programs and frequency distribution tables were used in data analysis. Computation of percentages were also used in analysis of socioeconomic variables as provided by the various respondents.

Data used was as follows;

Table 3.1 Data Variables Used

<b>Variable</b>	<b>Sub-variable</b>	<b>Measurements</b>
Food security	Meaning of food security Household food security	Three options given A one-month food recall
Production changes	Yields before and after greenhouse in terms of kg/acre	Variety crops grown in GH Harvest before and after GH
Income changes	Size of GH Income before and after adopting greenhouse	Size in hectares Changes in income levels
Challenges	Identified challenges	Rating of the challenges

## CHAPTER FOUR: RESULTS AND DISCUSSION

### 4.1 INTRODUCTION

Chapter four focuses on the research findings where interpretations of data is performed to ascertain whether the hypothesis are accepted or rejected or whether the research questions are answered as expected. The chapter also seeks to ascertain whether the objectives have been achieved by analyzing and interpreting the data. The focus area (which also translates to the independent variables) of the project is on the farm and green productivity, income changes, challenges to farmers, and mechanisms to improve farming among the farmers. The dependent variable is on the aspect of food security as measured by availability and accessibility of food for the household.

#### 4.1.1 Response Rate

The study had had a target of 71 respondents, were 44 respondents successfully returned the questionnaires, representing a 62% response rate. In this case, the response rate was met and was satisfactory as it exceeded the 50% mark that is recommended by some scholars as satisfactory for making generalizations to entire population in the study. The target for the focus group discussion was at least one, where the study met the target.

#### 4.1.2 Sub-County of the Respondent

Majority of the respondents were from Ikutha Sub-county as they accounted for about 91% of the total sampled respondents while the respondents from Mutomo were about 7% and 2.3% of the respondents were from Athi Sub-county. The information is as shown on the graph 4.1;

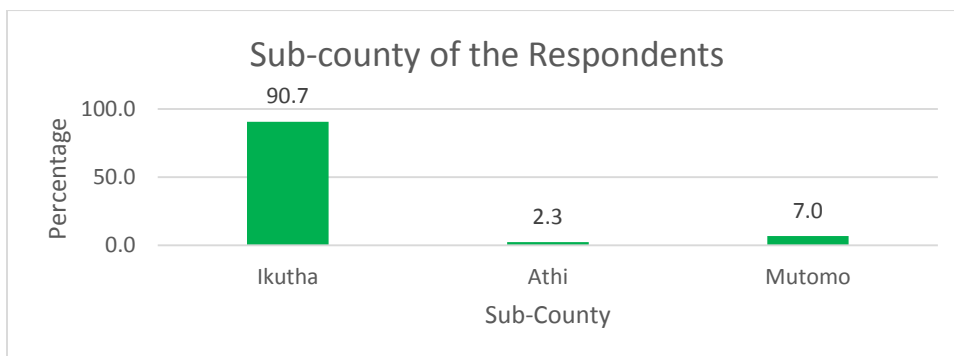


Figure 4.1 Sub-county of the Respondents

Source: field data 2018

### 4.1.3 Location of the Respondent

The study also sought to understand the location origin of the respondent and aid in understanding the areas where the greenhouse farmers were concentrated. The information is presented in figure 4.2 as shown;

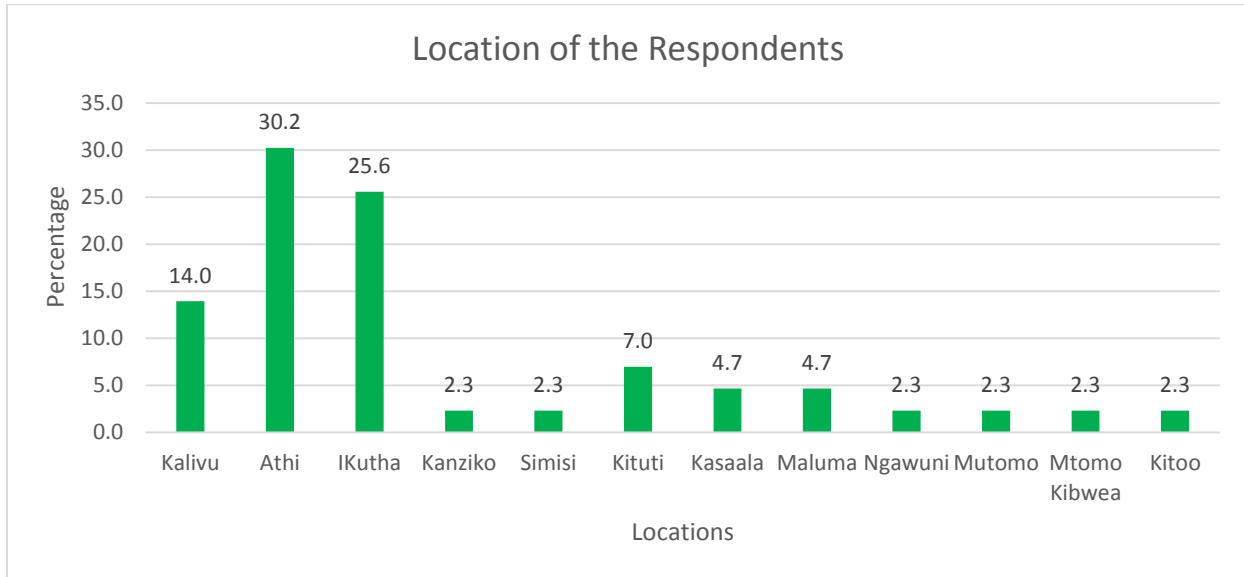


Figure 4.2 Location of the Respondent

Source: field data 2018

The majority of the respondents were from Athi location making 30% of the total sampled respondents while those from Ikutha and Kalivu were 26% and 14% respectively. Respondents from Kanziko, Simisi, Ngawuni, Mutomo, Kibwea, and Kitoo contributed each a total of 2.3% of the total respondents.

## 4.2 DEMOGRAPHIC CHARACTERISTICS

The section present the demographic characteristics that include the gender of the respondents, age, and the education level in relation to the greenhouse farming. The demographic characteristics help in defining the population from which the data was collected.

### 4.2.1 Age of the Respondents

The study also sought to establish the age brackets of the farmers to establish the age status of the majority of the farmers. In Kenya, and other developing countries, agriculture and rural farming has been left to the aged who do farming as a subsistence activity. The information was summarized in figure 4.3 as shown;

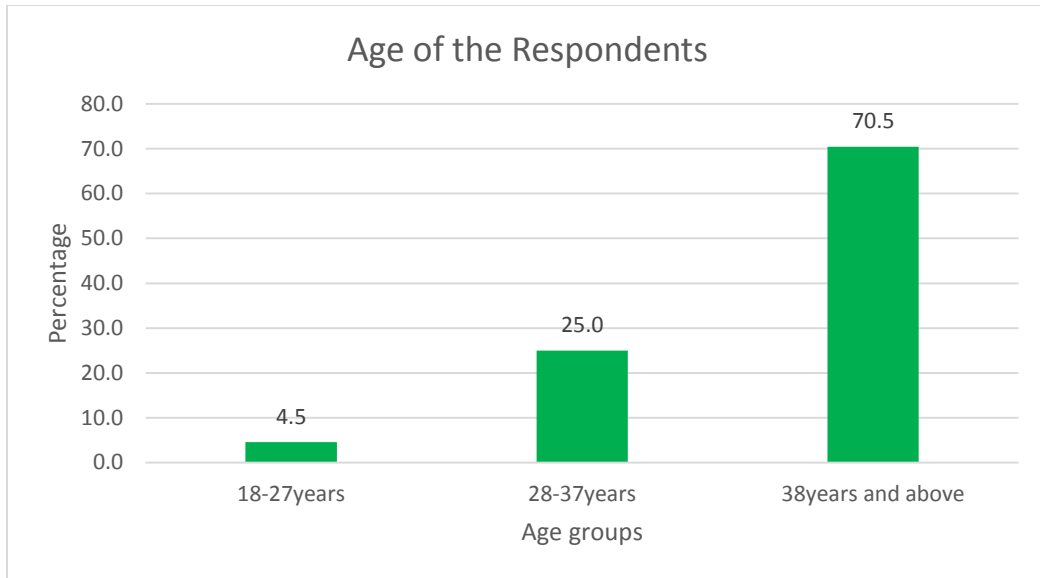


Figure 4.3 Age of the respondents  
Source: field data 2018

From the information presented, majority of the farmers were aged 38 years and above as they contributed to 71% of the total respondents. It was also observed that young farmers were least in the sampled group making a relatively small contribution of 4.5% of the total sampled population. Farmers aged 28 to 37 years contributed a quarter (25%) of the total respondents. From the information on the age of the respondents, it was confirmed that majority of the respondents were aged 3 years and above and thus majority of the greenhouse farmers in Ikutha region were confirmed to be aged 38 years and above.

#### 4.2.2 Gender of the Respondents

The researcher also sought to understand the gender differences for the sampled population to ascertain which gender forms the majority of the greenhouse farmers in Ikutha region. The information was summarized in figure 4.4 as shown;

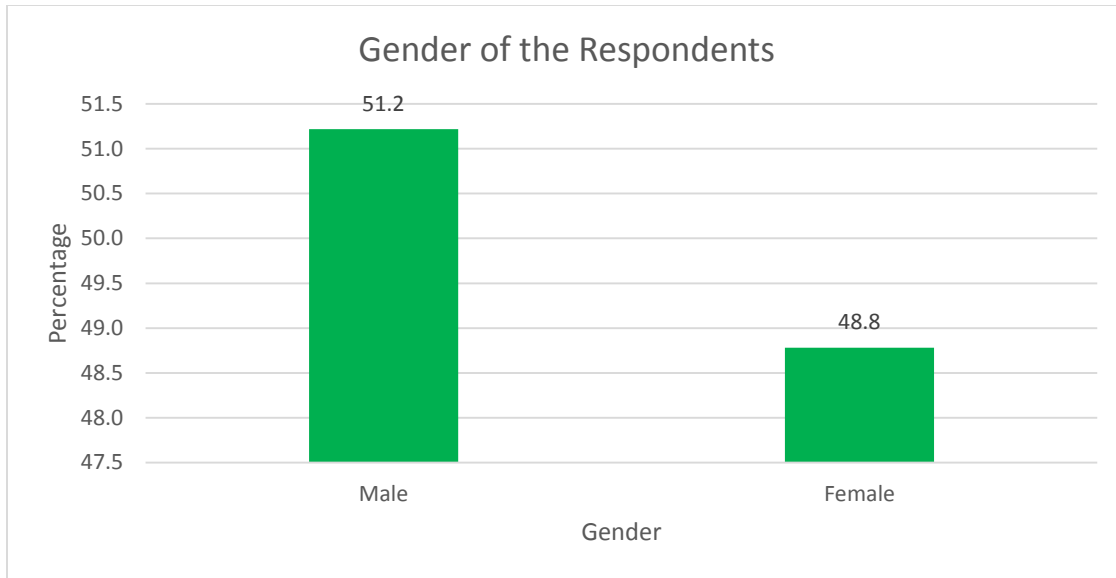


Figure 4.4 Gender of the Respondents  
Source: field data 2018

From the sampled respondents, it was found that male greenhouse farmers were slightly many at about 51% when compared to the female greenhouse farmers at about 49%. It can be seen however that the percentages are near similar with a difference margin of 2% between the groups. It can be said that female farmers have adopted greenhouse farming techniques as much as male farmers have.

#### 4.2.3 Level of Education

Education is a significant determinant of whether an individual can pick farming or not as shown by other studies. The study on greenhouse farming effects on food security sought to establish the level of education for the farmers and help determine the education level of majority of the farmers. The summary of the level of education is shown in figure 4.3;



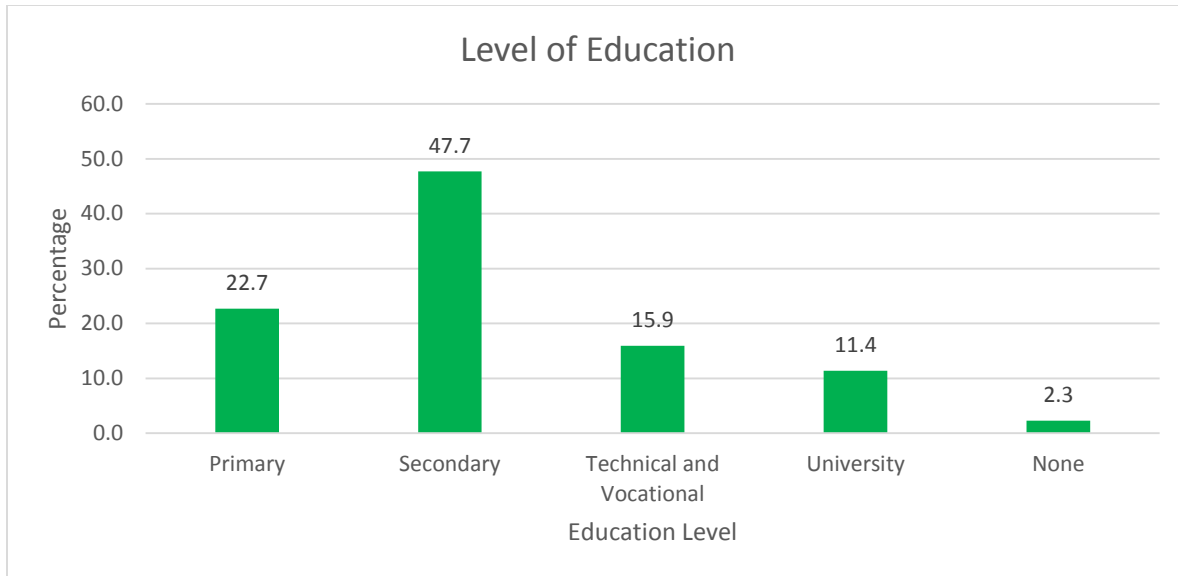


Figure 4.5 Level of Education  
Source: field data 2018

It was found that majority (48%) of the respondents had secondary level of education while those who had no education at all made 2.3% of the sampled respondents. Greenhouse farming needs technical knowhow especially on the management and control as well as having the right conditions for the targeted crops. Respondents with primary education and those with technical and vocational education contributed to 23% and 16% of the sampled farmers respectively. Greenhouse farmers with university education contributed to 11.4%, making it the smallest group of farmers practicing greenhouse farming. It can thus be said that having primary or secondary education was necessary for the Ikutha region farmers to participate in greenhouse farming as pointed by the information.

### 4.3 THE STATE OF FOOD SECURITY IN IKUTHA SUB-COUNTY

The aspects of cost of greenhouse farming was measured by perception of greenhouse farming, food security, and the experiences of the farmers in experiencing food security or food insecurity. Food security is the access by all people at all times to enough food for an active, healthy life. In this study, food security was described by having enough food, whether the kind of food the respondents wanted to eat or if not always not the kind of food they wanted to eat, as long as there was enough food for eating. All respondents agreed to have participated in greenhouse farming as 98% indicated that they were currently practicing and using greenhouse technology for farming.

### 4.3.1 Perceptions on the meaning of food security

Respondents were asked to select the best description of food security as per their knowledge and perception. Figure 4.6 shows the responses given on the meaning of food security among the respondents. Three options were given for the farmers to select from.

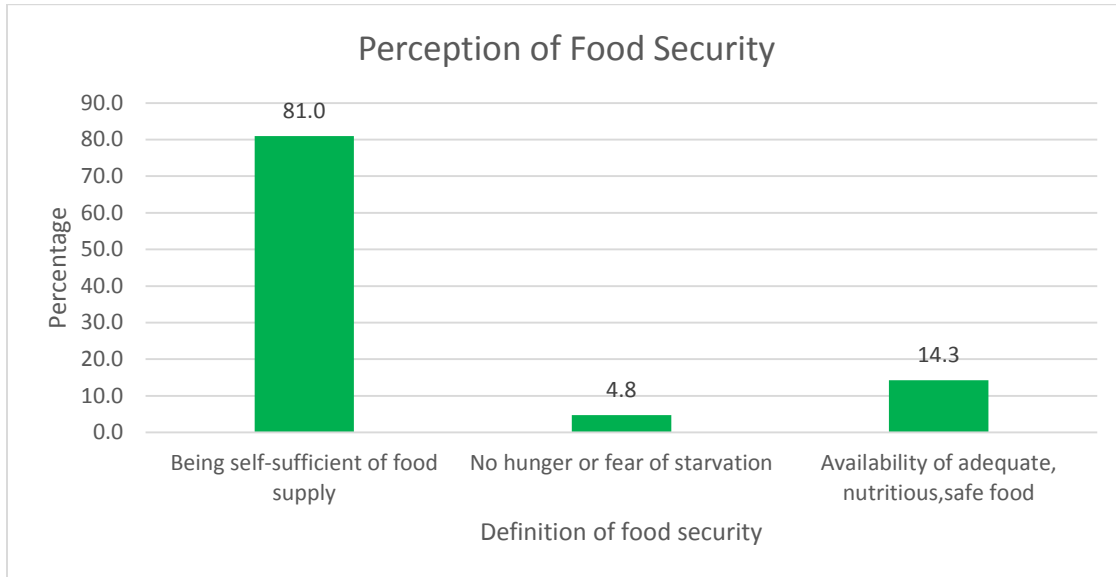


Figure 4.6 Food Security definition as per respondents

Source: field data 2018

Majority of the respondents at 81% described food security as being self-sufficient of food supply while another 14% indicated that food security was the availability of adequate, nutritious and safe food. The research assistants afterward (after the respondents gave their answers on their food security status) helped explaining to the farmers (respondents) the meaning of household food security. The other 5% of the respondents indicated that food security was having no hunger or fear of starvation. The two descriptions of being self-sufficient of food supply and having adequate nutritious and safe food for consumption had 95% of the respondents indicating that the farmers were aware of the situation that causes food (in) security.

### 4.3.2 Household Food Security in Ikutha Sub-County

The prompt was made to investigate presence of food insecurity among the sampled greenhouse farmers in Ikutha region. The researcher asked for general perception on whether the household had adequate food for consumption during the last twelve months from the period of survey. Four options were given with two having enough foods for consumptions and two others not having

adequate food to consume during the last twelve months. The summary of the findings are contained on figure 4.7 as shown;

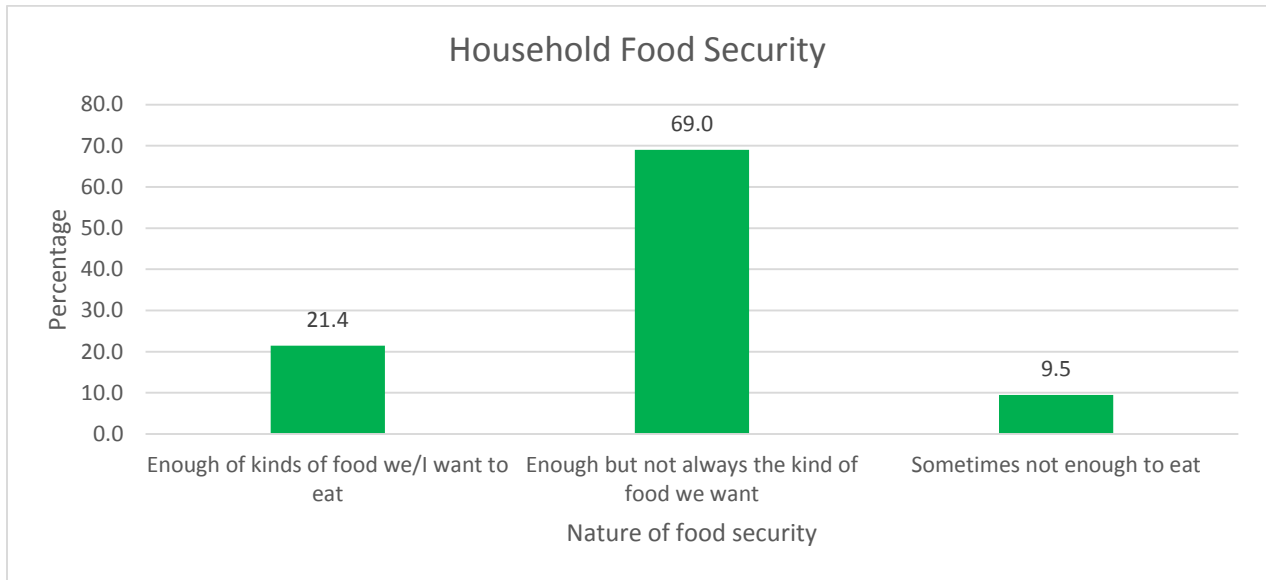


Figure 4.7 Household food security

Source: field data 2018

From the study data, it was found that about 9.5% of the sampled households experienced some form of food insecurity as they were not able to access sufficient food for all kinds for consuming for the previous twelve months. Majority of the respondents (69%) indicated that there was enough food but not always the kind of food they wanted to eat. It was found that about 21% of the respondents were food secure as they had enough kinds of food for them to eat throughout the twelve months. Majority of the households in ASALs of Kenya experience significant level of food insecurity. It can also be deduced that through adopting greenhouse farming, farmers have been able to improve their food security as majority at 90% felt that they had adequate food for consumption within the twelve months of the study.

#### **4.4 ASSESSMENT OF FARM PRODUCTIVITY BEFORE AND AFTER GREENHOUSE ADOPTION**

The section presents information and data on the farm productivity to ascertain whether there was any change in productivity before and after adopting greenhouse technology.

## 4.4.1 COST OF ACQUIRING AND INSTALLING GREENHOUSES

### 4.4.1.1 Construction of the Greenhouse in the area

The researcher wanted to establish who was involved in constructing of the greenhouses in the region. Through establishing the person who aided in constructing greenhouses, it was possible to estimate the costs of the overall installation of the greenhouses. Figure 4.8 shows the summary of the findings on who was responsible for construction of the greenhouses;



Figure 4.8 Person/Organization responsible (include the business name of the sponsoring organization)

Source: field data 2018

It was observed that over 81% of the respondents were supported by the organizations (ADRA and SASOL) that was supplying the greenhouses. There were a number of non-governmental organizations (NGOs) that were involved in aiding farmers improve their livelihoods and food security. Farmers were also involved in constructing their greenhouses as about 19% of the respondents indicated that they were the ones who constructed their greenhouses. Expertise in greenhouses was passed to the local farmers through capacity building trainings by the Kitui County Government and the local NGOs (including DAI, SASOL, and ADRA) where farmers learnt how to install and manage the greenhouses.

#### 4.4.1.2 Cost of Constructing the Greenhouse

The study sought to establish the estimated costs of their greenhouses through presenting closed-ended question with ranges of prices to the farmers. The summary of the responses were put on table 4.1 as shown;

Table 4.1 Range of Prices for Greenhouses

Range of price	Frequency	Valid Percent
1,000-49,999	8	18.5
100,000-149,999	3	7.4
150,000-199,999	5	11.1
200,000-249,999	2	3.7
250,000 and above	5	11.1
The organization invested everything	19	44.4
It cost me Nothing	2	3.7
<b>Total</b>	<b>44</b>	<b>100.0</b>

Source: field data 2018

From the information gathered, it was found that majority of respondents (farmers) had their greenhouses constructed by the sponsoring organizations. Over 44.4% of the respondents were helped by the organizations (SASOL and DAI) to put their greenhouses. A sizeable number of farmers at 18.5% indicated that their greenhouses cost them up to Ksh. 50,000 while another 18.5% indicated that their costs were up to ksh. 200,000. The cost of putting up greenhouses were thus varied as indicated on the summary of prices in table 4.1. The cost of greenhouses affects the likelihood of farmers adapting greenhouse farming. Higher costs might not favor the adoption of greenhouses and that will affect the state of food security for the farmers in Ikutha region.

#### 4.4.1.3 Cost of Irrigation System

Cost of irrigation system has a direct significant influence on food security since the farmers can shy away from installing irrigation systems. The study sought to establish the cost of irrigation system as it forms a constituent part of total greenhouse cost. The total cost of irrigation systems was presented on figure 4.9 as shown;

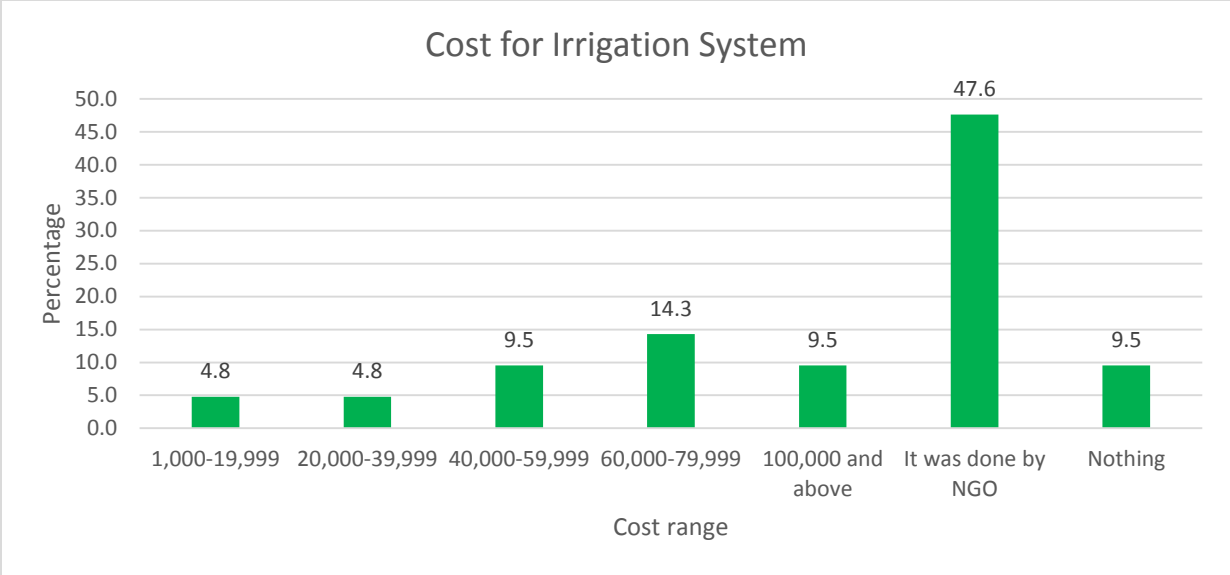


Figure 4.9 Cost of irrigation system  
 Source: field data 2018

Majority of the farmers (47.6) did not experience the cost directly as it was borne by the NGO (non-governmental organization) that installed the greenhouses. Those supported by NGOs and those who indicated “nothing” as their overall costs for installing irrigation system were 57%, pointing to the dependency by farmers on external support for agricultural support. There were a sizeable number of farmers representing 24% of the sampled respondents who spend between 40,000 to 80,000 while another 9.5% spend over 100,000 on irrigation systems.

**4.4.1.4 Cost of chemicals for greenhouse crops**

The use of chemicals is associated with increased production that translates to increased farm output. The researcher was interested in ascertaining whether there were high costs of chemicals as used in greenhouse crops. The summary of findings is contained on figure 4.10 as show;

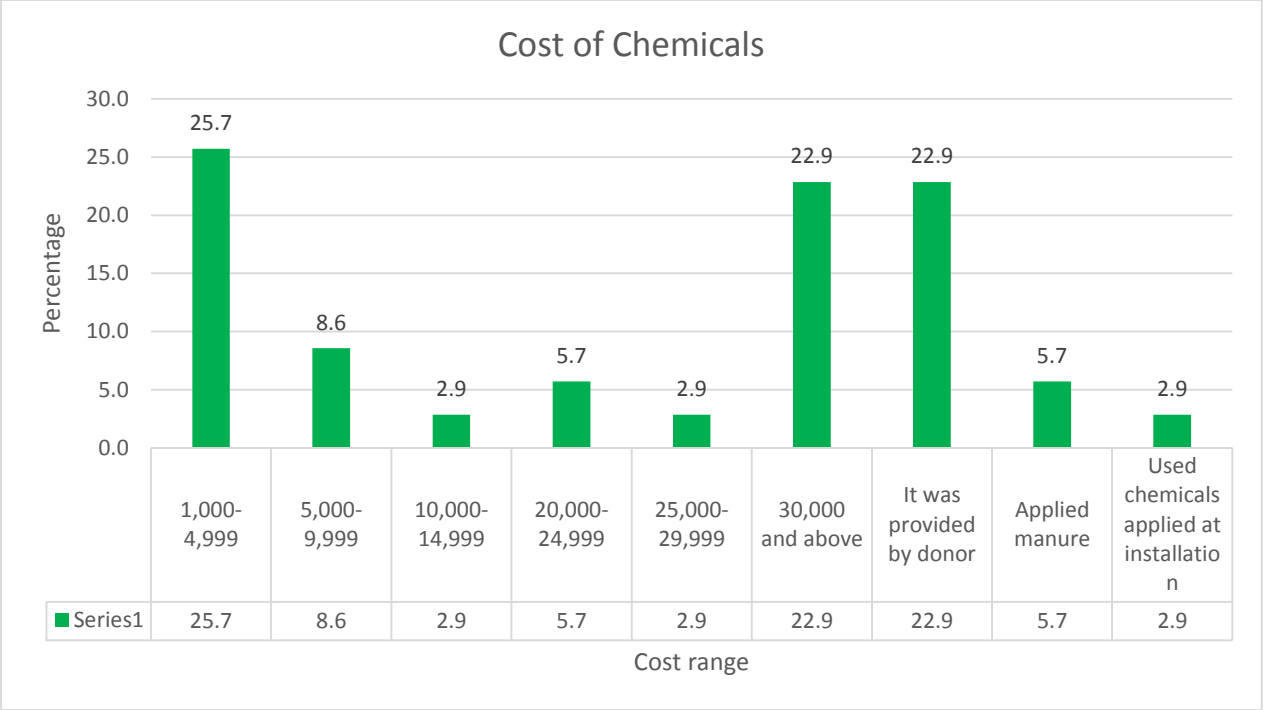


Figure 4.10 Cost of Chemicals  
 Source: field data 2018

It was observed that about 26% of the respondents spend between ksh. 1,000 and ksh. 5,000 on their farm chemicals. It was observed that about 23% of the respondents spend over ksh. 30,000 and other similar percentage of the respondents also indicated that their chemicals were provided by donors. A small number of respondents at 6% pointed out that they applied manure as their fertilizers. It was commendable that majority of the respondents spending amounts less than or up to ksh. 5000 on chemicals for greenhouse crops.

**4.4.2 KNOWLEDGE OF GREENHOUSE FARMING**

Knowledge of greenhouse practices and management of the crops under greenhouse enhances crop production that increases food security among the households. Knowledge on greenhouse skills was measured through presenting questions with options about training on maintaining and managing greenhouses and cultivation of crops under greenhouses.

**4.4.2.1 Training on maintaining and managing greenhouses**

The researcher sought to establish whether the farmers had attended any training on maintaining and managing greenhouses. Through training, the farmers are able to advance their capacities to

handle and improve management of the crops grown under greenhouses thus improving crop yields. The information was summarized on figure 4.11 as shown;

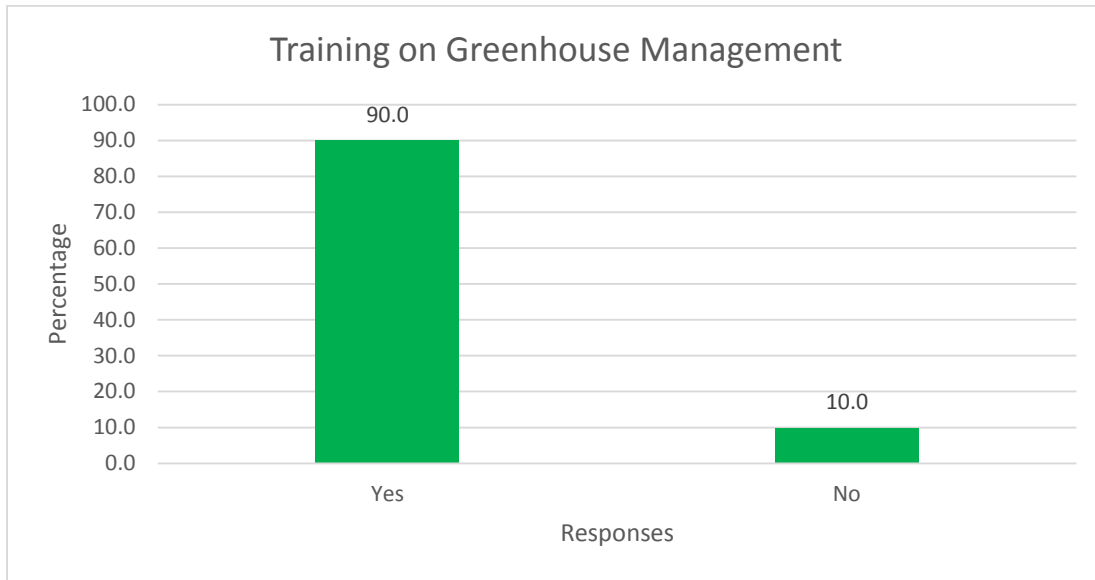


Figure 4.11 Training on Greenhouse management

Source: field data 2018

It was observed that majority (90%) of farmers in Ikutha region who owned or practiced greenhouse farming had at some point attended trainings to boost their capacity to handle and manage their crops under greenhouses. Only 10% of the respondents had not attended any training to improve their management capacity on greenhouse farming. Through supportive mechanism, farmers are able to increase their knowledge on managing greenhouses and thus translate to more yields improving the status of food security among farmers.

#### 4.4.2.2 Acquisition of skills to manage greenhouses

The researcher also wanted to understand how the farmers were able to acquire their skills in managing greenhouses and the crops planted. Since majority of the farmers acquired their greenhouses through sponsorships by NGOs, it was possible that they acquired their skills through seminars supported by the NGOs. Figure 4.12 shows the summary of the findings;



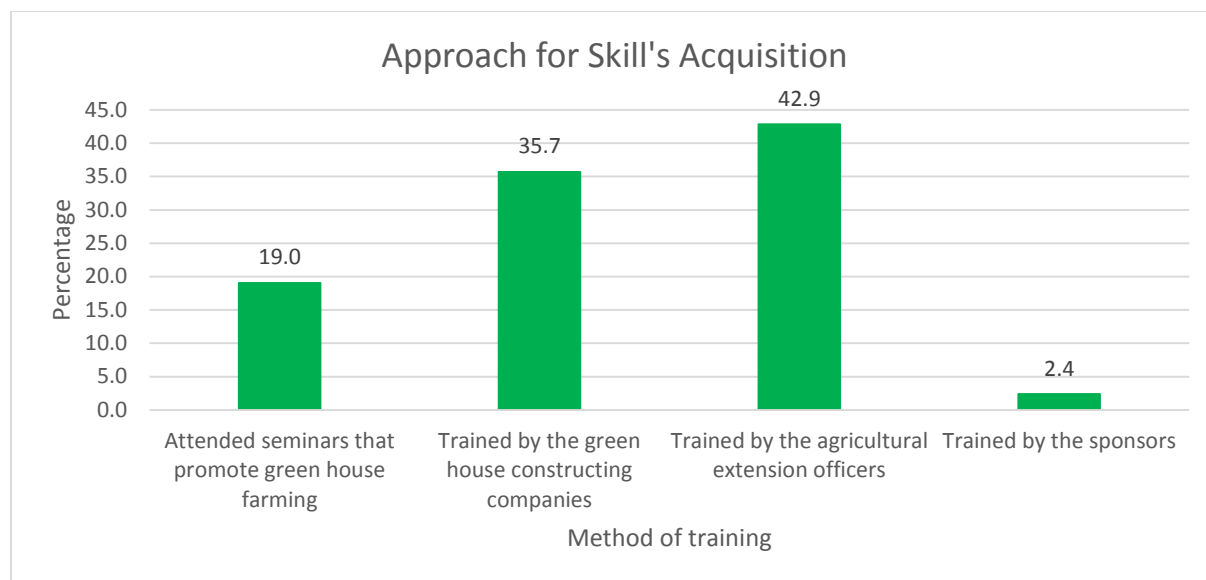


Figure 4.12 Method of acquiring greenhouse skills

Source: field data 2018

It was observed that extension officers and greenhouse constructing companies contributed the largest in terms of training workers where they were ranked 43% and 36% respectively. Extension officers are sent by the government to help farmers improve their farming methods and that informs the reason why they contributed much of the training to the farmers. It was also observed that around 19% of the farmers attended seminars to help them improve in their managing the greenhouses. Sponsors contributed to the least numbers of trained respondents as only 2.4% pointed out that sponsors were their main source of knowledge. Training of farmers by multi-sectorial departments is recommended for improving their knowledge on managing and maintaining greenhouses. The findings were also supported by over 93% of the sampled respondents who indicated that they had greenhouse farming skills especially for cultivating crops under greenhouses.

#### 4.4.2.3 Period of practicing greenhouse farming

The length of period invested for managing and planting crops under greenhouses is paramount to improving production through gaining of farming experience. It is expected that more experienced farmers would have improved greenhouse management practices and thus increase their crop yields translating to increased farmer resilience and food security. The information on period of involvement in greenhouse farming is presented on figure 4.13 as shown;

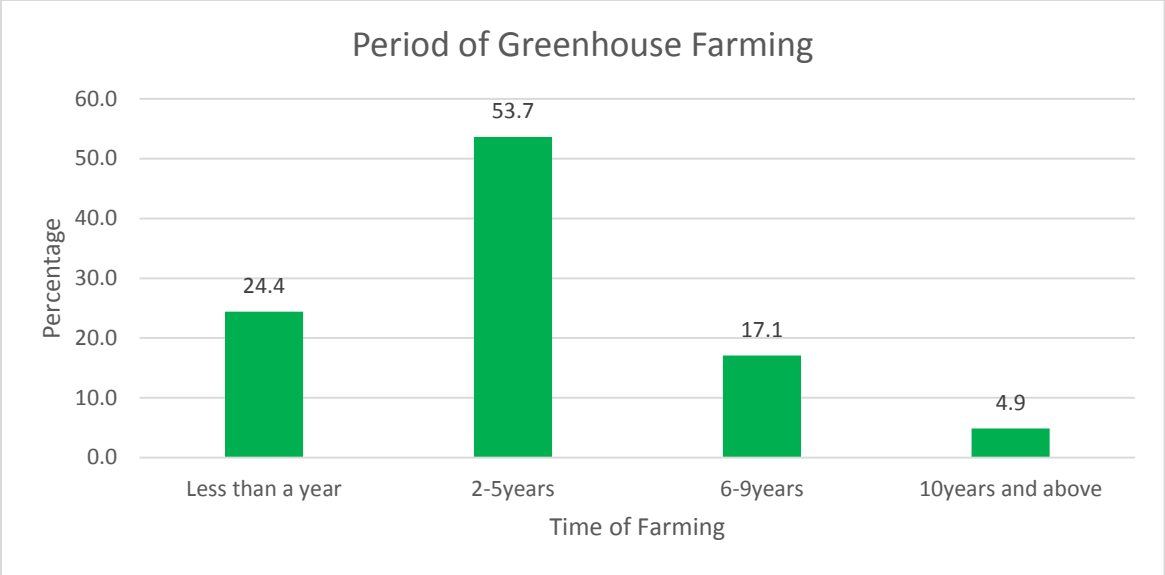


Figure 4.13 Period of greenhouse farming  
 Source: field data 2018

It was observed that over half of the respondents at 54% indicated that they had practiced greenhouse farming for between two and five years, and they were followed by those who had practiced greenhouse farming as they contributed to 24% of the sampled respondents. There was also a group of farmers who had practiced greenhouse farming for over ten years amounting to about 5% of the sampled respondents.

**4.4.2.4 Marketing of greenhouse crops**

Marketing of crops enhances farmers’ resilience and enhances their capacity to handle incidences of food insecurity. When markets are readily available for the farm produce, farmers are able to grown in large scale and thus can improve crop yields. The study sought to establish the major channels of marketing the greenhouse crops with the summary of findings presented on figure 4.14 as shown;

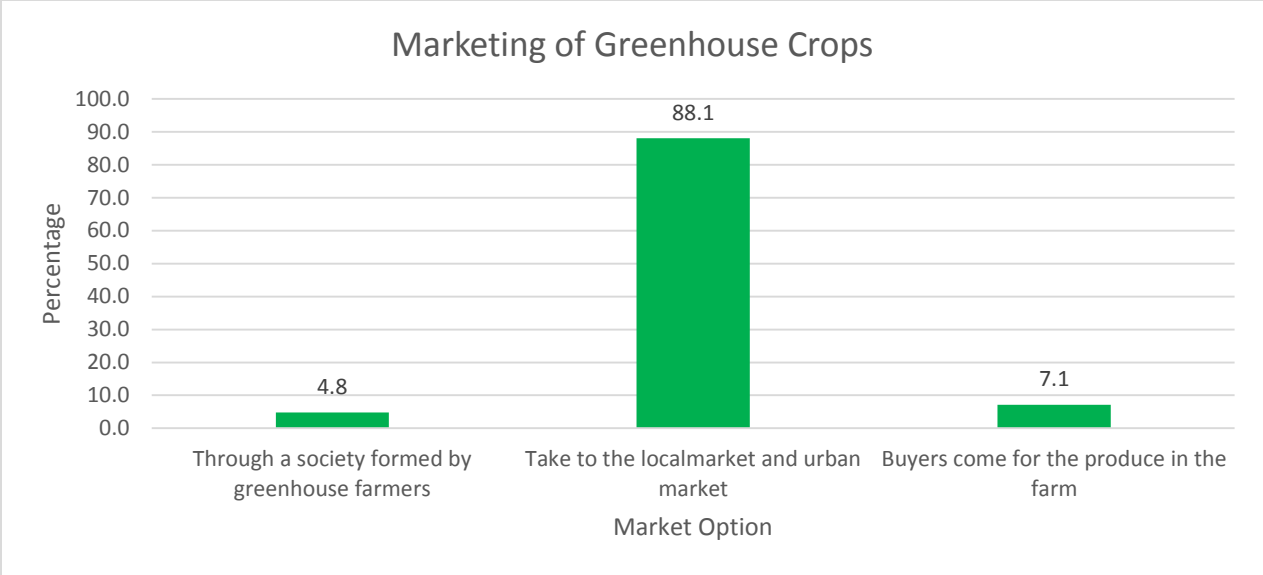


Figure 4.14 Market for greenhouse crops  
Source: field data 2018

Over 88% of the respondents sold their produce through the local markets and the nearest urban market. The findings apply across many farmers in ASALs where poor marketing systems for produce exist. Another 7% of the farmers indicated that buyers came to their farms to purchase their produce while around 5% of the farmers sold their produce through a society. Marketing of agricultural produce informs the nature of benefits farmers are able to accrue from produce as most local markets buy with low prices as opposed to controlled and organized urban markets.

**4.4.3 DIVERSIFICATION IN THE GREENHOUSE FARMING**

Diversification of crops grown under greenhouse was measured through understanding the nature of crops grown. Respondents were asked to name the crops they ever planted under greenhouses and the accrued benefits.

**4.4.3.1 Crops grown in Greenhouses**

The study also sought to know the majority of crops grown under greenhouses among the farmers in Ikutha region. Respondents had agreed that they planted a variety of crops and thus it was possible for one farmer to have more than one crop under the greenhouse. Table 4.2 shows the summary of crops grown by greenhouse farmers in Ikutha region;

Table 4.2 Crops grown

<b>Crop</b>	<b>Frequency</b>	<b>Valid Percent</b>
Tomatoes	42	95.5
Vegetables	16	36.4
Fruits	2	4.5.
Capsicum	3	7.5
Onions	4	9.1

Source: field data 2018

Majority of the farmers at 96% in Ikutha region planted tomatoes as the main crop in their greenhouses. The second most grown crop was vegetables which included sukuma wiki (kales) at 36%. Onions, capsicum, and fruits were the other crops grown under greenhouses by about 9%, 7.5%, and 4.5% of the farmers sampled. Farmers need to be trained and informed of the available agricultural extension officers to help them improve their farming practices.

#### **4.4.3.2 Planting of variety of crops**

Planting a variety of crops was seen as a major practice embraced by greenhouse farmers in Ikutha region. The practice of planting a variety of crops aids farmers in spreading their risks and ensuring that they do not suffer losses when one crop fails. Table 4.3 shows the summary of findings about planting of variety of crops;

Table 4.3 Variety of crops planted

<b>Scale</b>	<b>Frequency</b>	<b>Valid Percent</b>
Yes	16	43.2
No	21	56.8
<b>Total</b>	<b>37</b>	<b>100.0</b>

Source: field data 2018

It was found that a sizeable number of farmers at 57% do not embrace planting a variety of crops in their greenhouses while about 43% of farmers embrace planting variety, often planting two crops in one greenhouse. The practice of having different crops under one greenhouse is often found among the rural farmers who prefer to have a variety of crops that improve their chances to improve their livelihoods and ability to strengthen their resilience on food insecurity.

#### 4.4.4 SIZE OF GREENHOUSE

The study sought to identify the size of land and greenhouse farm and help relate it to production. The aspects included include the size of farmer's land, the size of greenhouse farm, the number of greenhouses on the farm, and government policies embraced to ensure greenhouse farming is effective among the farmers in Ikutha region.

##### 4.4.4.1 Size of farmers' land

The size of the farmer's land influences the available land for putting under greenhouse farming. The size of acreage is presented on figure 4.15 as shown;

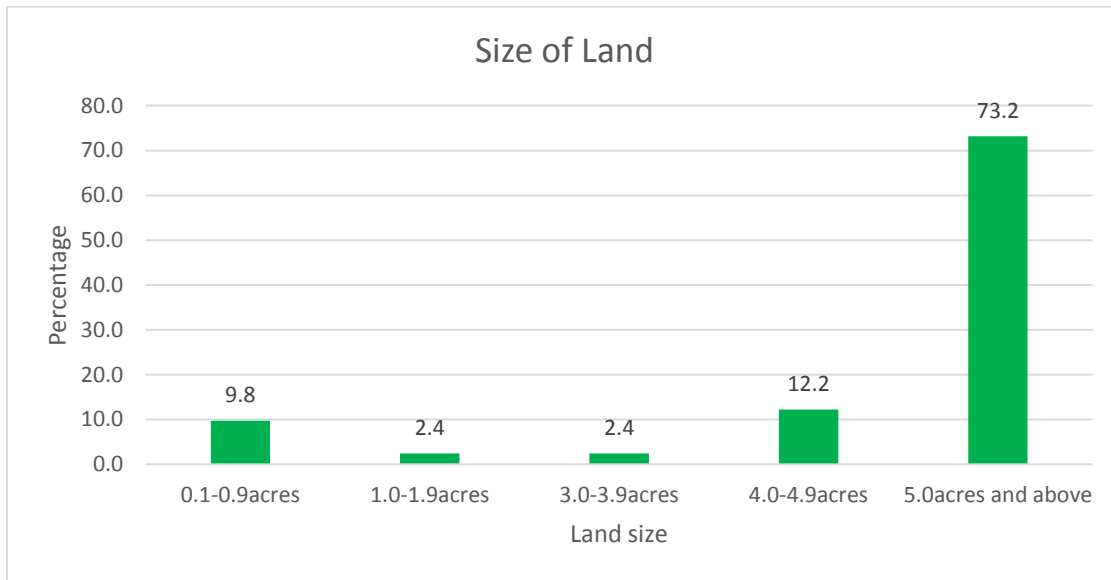


Figure 4.15 Size of Land

Source: field data 2018

From the respondents, it was observed that over 73% of the farmers had their farms' acreage of above 5.0 acres. There were 12% of the respondents who had 4.0 to 3.9 acres, and there were others about 10% who had between 0.1 and 0.9 acres. The majority of respondents indicated that their lands were big enough to accommodate some numbers of greenhouses.

##### 4.4.4.2 Size of the greenhouse farm

The study found that majority of the farmers had their greenhouse farm size of 9mX30m as it contributed to 54% of the total respondents. The summary of findings were indicated in figure 4.16 as shown;

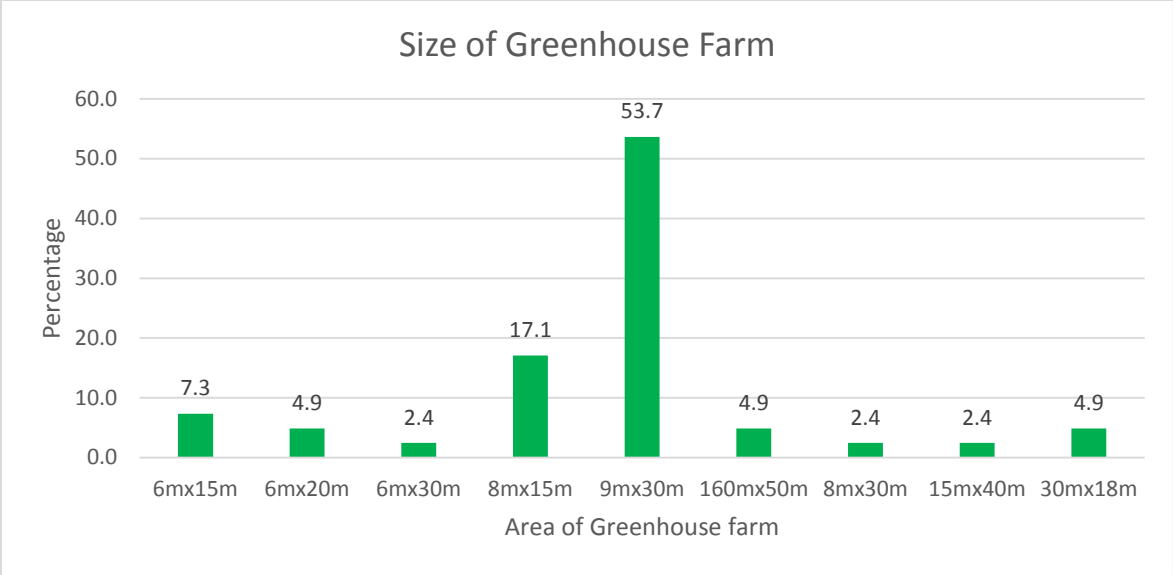


Figure 4.16 size of greenhouse farm  
 Source: field data 2018

It was also found that about 17% of the respondents had greenhouse farm sizes of 8mX15m as indicated on the figure 4.19. Majority of the respondents had the standard size greenhouse of 9mX30m.

**4.4.4.3 Number of greenhouses on the farm**

The stud also sought to understand the majority of the farmers and the number of greenhouses owned by the farmers. The summary of information is shown on figure 4.17 as shown;

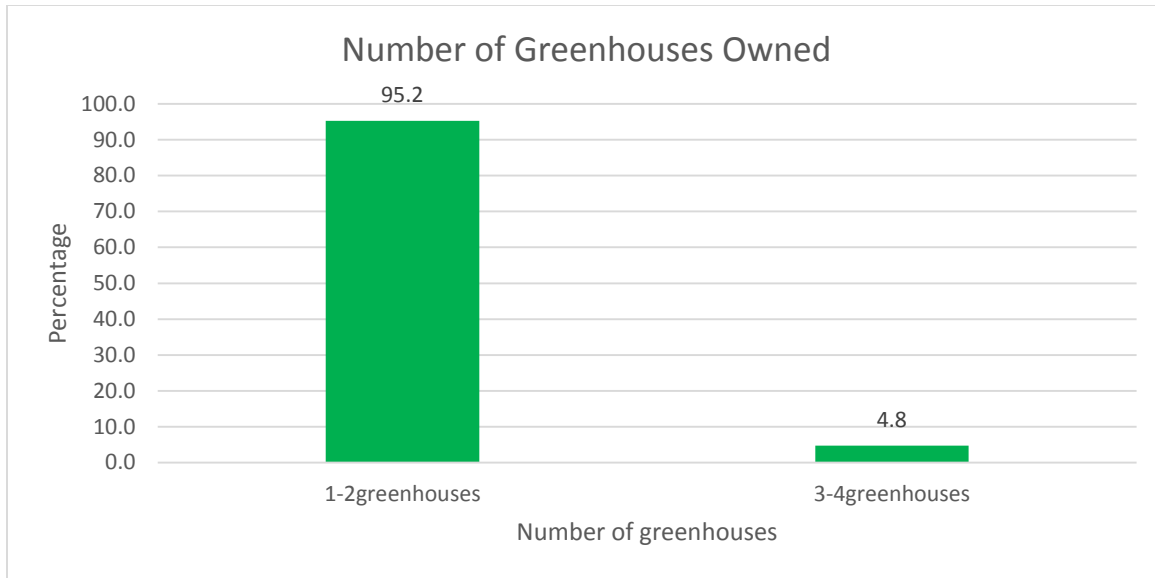


Figure 4.17 Number of greenhouses owned

Source: field data 2018

It was observed that 95% of the respondents owned one to two greenhouses as they were the majority while the minority owned between three to four greenhouses. The number of greenhouses indicate the likelihood of a farmer engaging in more extensive greenhouse farming.

#### 4.4.5 PRODUCTION BEFORE AND AFTER GREENHOUSE ADOPTION

The yields before and after adopting greenhouses are presented in this section, with different types of crops presented. For instance, onions, capsicum, tomatoes and vegetables among others are presented in terms of kilograms before and after adoption of greenhouse.

##### 4.4.5.1 Production before and after adoption of greenhouse

Under table 4.2, the crops mostly grown include tomatoes and vegetables, with a focus on kales. From the data collected, it was found that there were many gaps especially on remembering the right amounts of tomatoes and kales harvested. It was from the compilation of that data that the study was able to come up with the average and the standard deviations of the crop production as shown on table 4.4.

Table 4.4 Summary of production before and after greenhouse adoption

Statistic	Tomatoes in kgs before green house adoption in 2010	Tomatoes in kgs after green house adoption in 2010	Kales in kgs after greenhou se adoption in 2010	Kales in kgs before greenhous e adoption in 2010	Kales in kgs after greenho use adoption in 2011	Kales in kgs after greenho use adoption in 2012	Kales in kgs after greenhou se adoption in 2013	Kales in kgs after greenho use adoption in 2014
Mean	451.11	1098.50	605.00	190.00	780.00	720.00	440.00	500.00
Median	240.00	700.00	600.00	180.00	760.00	720.00	400.00	500.00
Std. Deviation	595.744	1194.124	121.518	164.520	90.921		262.298	424.264
Variance	354911.111	1425932.455	14766.667	27066.667	8266.667		68800.000	180000.000
Skewness	2.726	2.386	.023	.356	.894		.670	
Std. Error of Skewness	.717	.637	1.014	1.014	1.014		1.225	
Range	1880	4300	220	400	200	0	520	600
Sum	4060	13182	2420	760	3120	720	1320	1000

Source: Field data 2018

It was observed that the respondents had easy time remembering the amount of kales harvested and thus its data was available for years from 2010 to the year 2014 as shown on table 4.4. The researcher selected to use the tomato yields for the year 2014 as they were more recent and complete as compared to yields from other years which had gas.

On the tomato yields, it was observed that the mean yields for 2014 before adopting greenhouses was 451 kilograms harvested from the greenhouse and it increased to 1098.5 kilograms per harvest from the greenhouse after installing greenhouses. The change was also evident in the median amount as before the greenhouse it was 240kg per farmer as compared to 700 kg per farmer after adopting greenhouse. There was positive skewedness for both years, before and after greenhouse adoption. It was thus evident there was a change in production from the adoption of greenhouses among the farmers in Ikutha region.



For the kales (and other vegetables), there was also similar trend of production increasing after adopting greenhouse farming. In 2010, the mean for kale production was 190 kg per greenhouse before and 604kg per greenhouse after adopting greenhouse. The median value also reflected the changes. In 2011, farmers without greenhouse managed to produce a mean yield of 190kg as compared to 780kg after using greenhouse. In the subsequent years after adopting greenhouse technology, production steadily increased. Table 4.4 shows the other years and performances, indicating that there was significant change in yield for the two periods, before and after adopting greenhouse farming.

#### 4.4.5.2 Average amount of production in kilograms per hectare

There were varied amounts mentioned by farmers in terms of kilograms produced per hectare per year. Most of the farmers were giving estimates as the process involved recalling the amount of harvest. With recall periods going back to 2010, some farmers had challenge in recalling the amounts of onions or tomatoes harvested. Since the study wanted to analyze the yields in uniform units, they were converted to kilograms per hectare. The summary of the findings is indicated on table 4.5 as shown;

Table 4.5 Produce (Harvests) in kilograms per acre for tomatoes for 2014

<b>Amount</b>	<b>Frequency</b>	<b>Valid Percentage</b>
1 -200 kgs	4	8.9
201 – 500 kgs	3	6.9
501 - 800 kg	4	9.1
801 - 1000 kg	18	40.9
1001 -1200 kg	4	9.1
1201 – 1500 kg	6	13.7
1501 – 1800 kg	4	9.1
1801 + kg	1	2.3
<b>Total</b>	<b>44</b>	<b>100.0</b>

Source: Field data 2018

The majority of farmers indicated that they got about 900 kilograms per hectare of tomatoes with majority of members at 41%. Tomatoes were mostly farmed in greenhouses hence it was possible to shown yields from different farmers. There were other farmers who indicated that they harvested around 100kgs per hectare amounting to about 8.9% of the total respondents. The other production per hectare is shown on table 4.5 as shown.

#### 4.4.5.3 Greenhouse technology a positive technology

It was sought from the farmers to establish whether embracing greenhouse technology was a positive technology or not. The responses are contained on figure 4.18 as shown;

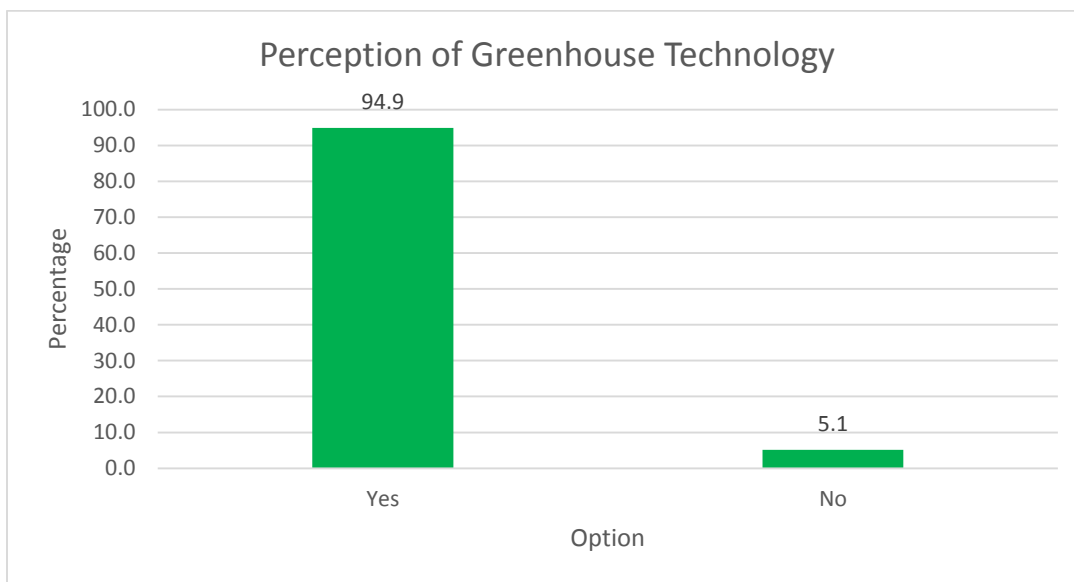


Figure 4.18 Perceptions on Greenhouse Technology

Source: field data 2018

Majority of farmers in Ikutha region felt that greenhouse technology was positive and was adding benefits to farmers. Only about 5% felt that greenhouse farming technology was not important to farmers. As expected, farmers were of the opinion that greenhouse farming practices had significant changes in their farming processes and production. For those who said no, they gave reasons where 50% (n=2) indicated that there was less amount of water, land and labor to support greenhouse technology, and others indicated that there was no positive impact because greenhouse was swept away by flooding water. From the observer's point of view, those who felt that

greenhouse technology was not helpful had other factors related to environment or sociocultural aspects that limited their capacity to receive their full potentials of adopting greenhouses.

#### **4.4.6 TESTING HYPOTHESIS FOR FARM YIELDS**

The objective was satisfied through testing the hypothesis to ascertain whether the incomes and production was the same for the periods before and after the farmers embraced greenhouse farming. The first two objectives for comparing productivity and income before and after greenhouse installation were treated to comparison of the means for the two groups. Using SPSS (statistical package for social scientists), independent sample t-test was used as it helped compare the two means, mean for yields and incomes before and yields and incomes after adopting greenhouse farming. The paired sample t-test determines whether there is statistically significant difference between means for two related group means.

##### **4.4.6.1 Productivity before and after greenhouse adoption**

The study compared two means, for each crop identified from the greenhouse farmers. Three crops were compared including tomatoes, onions and kales as they had the most uniform data. The test used was through comparing means and picking the paired sample t-test which is used for two means which are for a similar group. In this case, the farmers are the same but the yields are different for the period before greenhouse and period after greenhouse. The two hypothesis are as shown;

H0:  $\mu$  yields before greenhouse =  $\mu$  yields after greenhouse

H1:  $\mu$  yields before greenhouse  $\neq$   $\mu$  yields after greenhouse

Table 4.6 shows the output summary

Table 4.6 Paired samples correlations production  
Paired Samples Correlations

	N	Correlation	Sig.
Pair 1 Total yields before greenhouse & tomato yields after greenhouse	47	.038	.800
Pair 2 Kales yields before GH & Kale yields after GH	11	-.202	.551
Pair 3 Onions yields before GH & Onions after GH	2	1.000	.000

Source: field data 2018

For the three picked crops, tomatoes, kales and onions (which are mostly grown by farmers in Ikutha region), their p-value (significant value on the fourth column on table 4.8) was greater than alpha level, which is 0.05, representing the 95% confidence level.

#### 4.4.6.2 Results of pared sample T-test

Table 4.7 Paired Sample Test results for significance and t-test  
Paired Samples Test

		Paired Differences				t	df	Sig. (2-tailed)	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower				Upper
Pair 1	Total yields before greenhouse - tomato yields after greenhouse	781.404	1664.699	242.821	292.630	1270.178	3.218	46	.002
Pair 2	Kales yields before GH - Kale yields after GH	-432.727	267.024	80.511	-612.116	-253.338	-5.375	10	.000
Pair 3	Onions yields before GH - Onions after GH	-4750.000	1060.660	750.000	-14279.654	4779.654	-6.333	1	.100

Source: field data 2018

From the paired sample test results, the significant values for the three pairs were determined with the two major crops, tomatoes and kales having p values less than 0.05. If  $p \text{ value} \leq \alpha$ , then reject  $H_0$  (which indicates that  $\mu$  yields before greenhouse =  $\mu$  yields after greenhouse). From the observed and calculated t-values and significance values (p values), the p value for tomatoes was 0.002, less than alpha level of 0.05 and therefore the null hypothesis was **rejected**, the two means were not the same. For the tomatoes and kales, the means were not the same and thus it was concluded that mean production before adopting greenhouse was not the same as mean production after greenhouse adoption. It can be indicated that there was significant change in production after farmers adopted greenhouse farming in Ikutha region. For the case of onions, the data was not adequate enough to inform on significance test for comparing means using the paired sample tests.

## 4.5 ANALYSIS OF INCOME OF FARMING GROUPS BEFORE AND AFTER GREENHOUSE ADOPTION

It was expected that when farmers changed their farming styles and technology, there was some significant change in income earned from the greenhouse farming among the farmers in Ikutha region.

### 4.5.1 GREENHOUSE TECHNOLOGY AND INCOME

The study sought to establish the impacts of greenhouse effects on income levels.

#### 4.5.1.1 Effect of Greenhouse Technology on Income levels

The study sought to understand the perception of farmers on whether embracing greenhouse technology changes the amount of incomes among the local farmers. The information was contained on figure 4.19 as shown;

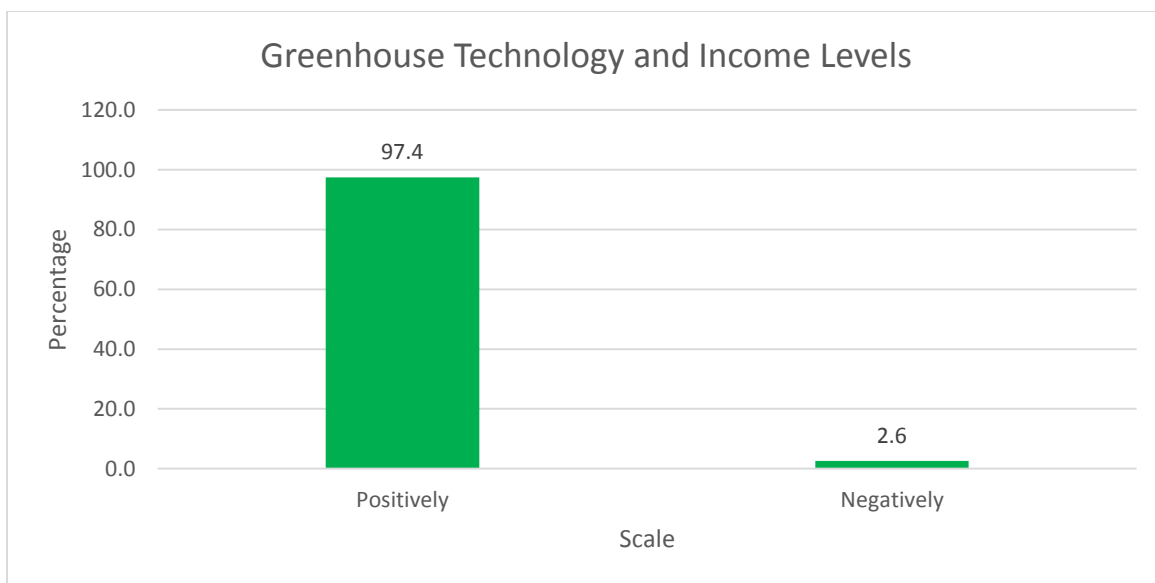


Figure 4.19 Greenhouse Technology and Income Levels

Source: field data 2018

It was observed that almost all the members at 97% positively identified with greenhouse technology as it influenced the levels of income. Income among the farmers arises from increased yields and thus translating to increased income among the farmers. From secondary literature, it has been found that embracing greenhouse technology increases income levels of farmers. Members gave reasons for improved income including increased productivity (44%), increased

income (37%), increased market demand (2%), and some members feeling that greenhouse was always free from pests and diseases (5%). Members also felt that embracing greenhouse technology had improved their livelihoods through increased yields and prices.

#### 4.5.1.2 Greenhouse Technology and positive Impact in Future Earnings

Respondents also felt that there was expected positive impact in future as it would influence crop yields and consequently increasing the income levels. Over 90% of members felt that there is positive future among the farmers who adopt greenhouse technology. Figure 4.20 shows the summary of findings on the perception of future impacts on income from farmers;

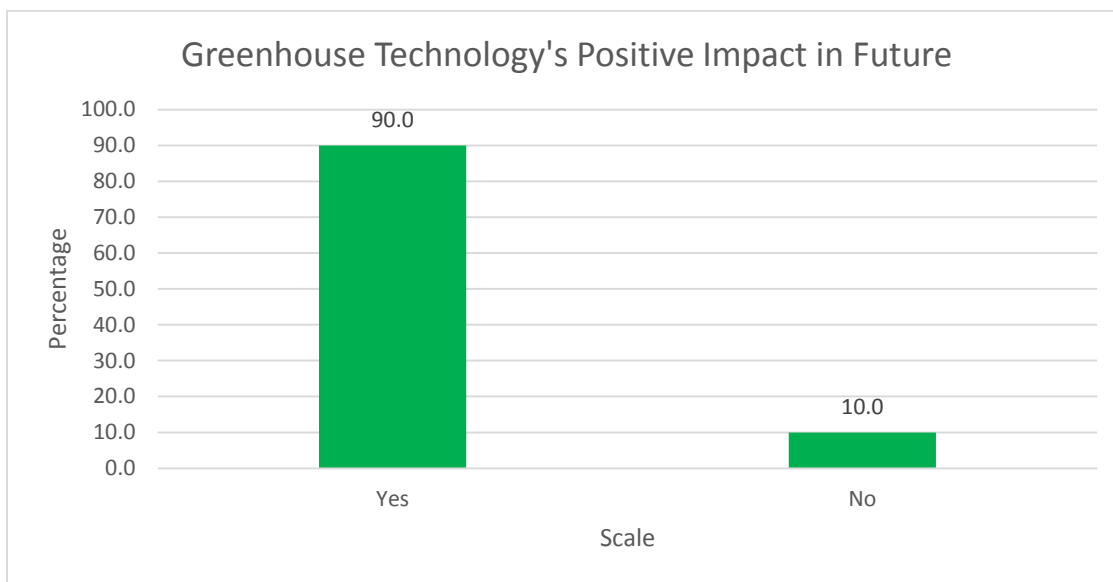


Figure 4.20 Greenhouse technology positive impact in future

Source: field data 2018

It was also observed that about 10% of the respondents felt that greenhouse technology would not have positive impacts on the future income of farmers. It is expected that improved farming technologies would positively affect the amount of income farmers would earn. Members who disagreed that greenhouse technology would improve productivity indicated that positive measures would be realized if only good measures would be put in place to ensure farmers benefit from the technology. Other respondents also indicated that there would be increase in income among the farmers while others pointed out that there was increased production among the farmers. Some challenges were mentioned as the reason why greenhouse technology would not benefit the

common farmers in Ikutha region. Some reasons given included lack of water and pesticides, extra usage of fuel that increases the cost of farming operations, worn out greenhouses due to poor maintenance, and while some of respondents indicated that their greenhouses were not operational.

#### 4.5.2 TESTING HYPOTHESIS

The objectives was satisfied through testing the hypothesis to ascertain whether the incomes and production was the same for the periods before and after the farmers embraced greenhouse farming. The first two objectives for comparing productivity and income before and after greenhouse installation were treated to comparison of the means for the two groups. Using SPSS (statistical package for social scientists), independent sample t-test was used as it helped compare the two means, mean for yields and incomes before and yields and incomes after adopting greenhouse farming. The paired sample t-test determines whether there is statistically significant difference between means for two related group means.

##### 4.5.2.1 Paired Samples Correlations for Income of the farmers before and after greenhouse adoption

Income, like yields, was subjected to the process of comparing means for the two periods. The paired sample t-test was performed. The two means included one for the period before and the other period after adopting greenhouse farming.

Table 4.8 Paired Samples Correlations for income

##### Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Tomato income before greenhouse & tomato income after greenhouse	65	.041	.745
Pair 2	Kales Income before GH & Kale Income after GH	18	-.271	.278
Pair 3	Onions Income before GH & Onions Income after GH	4	-.359	.641

Source: field data 2018



From table 4.10 on the paired results, the significance results were all above 0.05 showing that the correlation was positive (0.041) for the two means for tomatoes and negative (-0.271 for kales and -.359 for onions) for the two means covering kales and onions.

The two hypothesis are as shown;

H0:  $\mu$  income before greenhouse =  $\mu$  income after greenhouse

H1:  $\mu$  income before greenhouse  $\neq$   $\mu$  income after greenhouse

The study sought to calculate the correlations between the means for the income gained before adopting greenhouse farming, and comparing it to incomes gained after adopting greenhouse farming. Three crops were major in terms of the recalls from the farmers and thus they were included in the samples test. The summary of the analysis is contained on table 4.9 where t-test and significance (p values) results are shown.

Table 4.9 Paired Samples Test Results

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Tomato income before greenhouse - tomato income after greenhouse	-24210.769	75770.237	9398.141	-42985.715	-5435.824	-2.576	64	.012
Pair 2 Kales Income before GH - Kale Income after GH	10083.333	51690.894	12183.661	-15621.944	35788.610	.828	17	.419
Pair 3 Onions Income before GH - Onions Income after GH	-4600.000	8475.848	4237.924	-18086.966	8886.966	-1.085	3	.357

Source: field data 2018

From the paired samples test, the significance test was found to be 0.012 for tomatoes and thus following the rule of thumb in interpreting the T-test results, (If  $p \text{ value} \leq \alpha$ , then reject  $H_0$ .) the null hypothesis ( $H_0: \mu \text{ income before greenhouse} = \mu \text{ income after greenhouse}$ ) was **rejected**. It was thus concluded that the income generated from tomatoes grown using greenhouses was greater than the income generated from farms that are not using greenhouses. For kales and onions, the p value was greater than 0.05 and thus the null hypothesis was not rejected, indicating that the income generated from kales and onions from farms not adopting greenhouses was not different from the income generated from kales and onions from farms adopting greenhouse farming. One possible reason given for the trend for the kales and onions was the lack of adequate data (recalled data from past harvests and sales) with the few data that could also be compromised by estimation.

#### 4.6 CHALLENGES FACED BY GREENHOUSE FARMERS IN IKUTHA REGION

The section was made to identify challenges that greenhouse farmers experience and that can help improve their performance. The challenges were identified based on the perceptions from the farmers as well as their solutions.

##### 4.6.1 Have experienced challenges

Majority of the respondents felt that there were challenges affecting greenhouse farming among the farmers in Ikutha Sub-county. The information was summarized on figure 4.21 as shown;

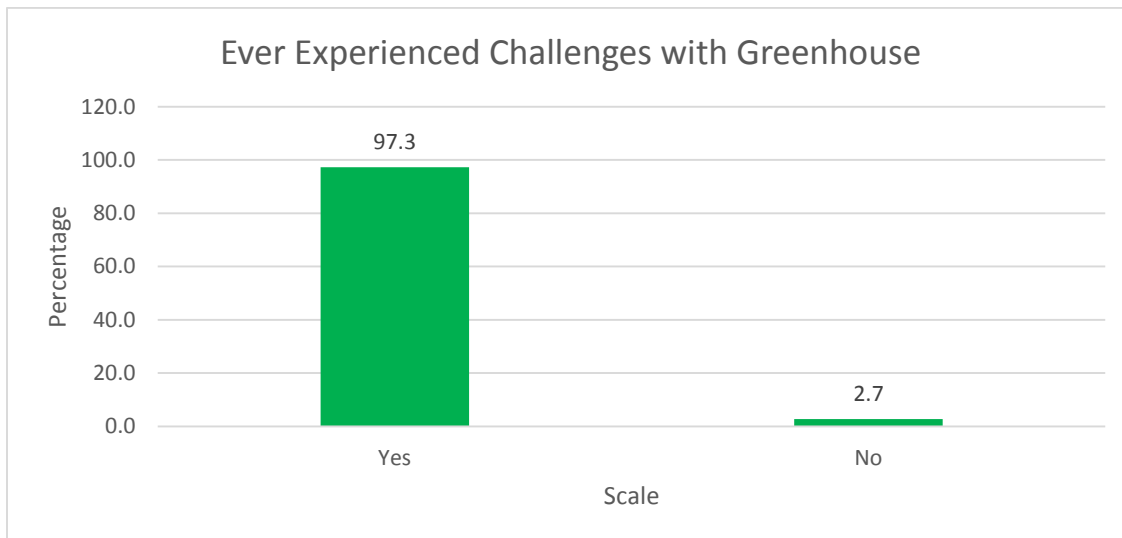


Figure 4.21 Challenges experienced with greenhouse farming

Source: field data 2018

All members among the farmers felt that there were challenges in greenhouse farming. Only about 3% of the respondents felt that greenhouse farming was perfect and that there was no challenges associated with greenhouse farming.

#### 4.6.2 Identified Challenges

The study also sought to identify the major challenges identified from the farmers around the Ikutha region. Unavailability of water supply (33%), diseases of crop (33%), and high wind that blew the greenhouses at 17%. There are several challenges that were identified as shown. Figure 4.22 shows the summary of challenges identified;

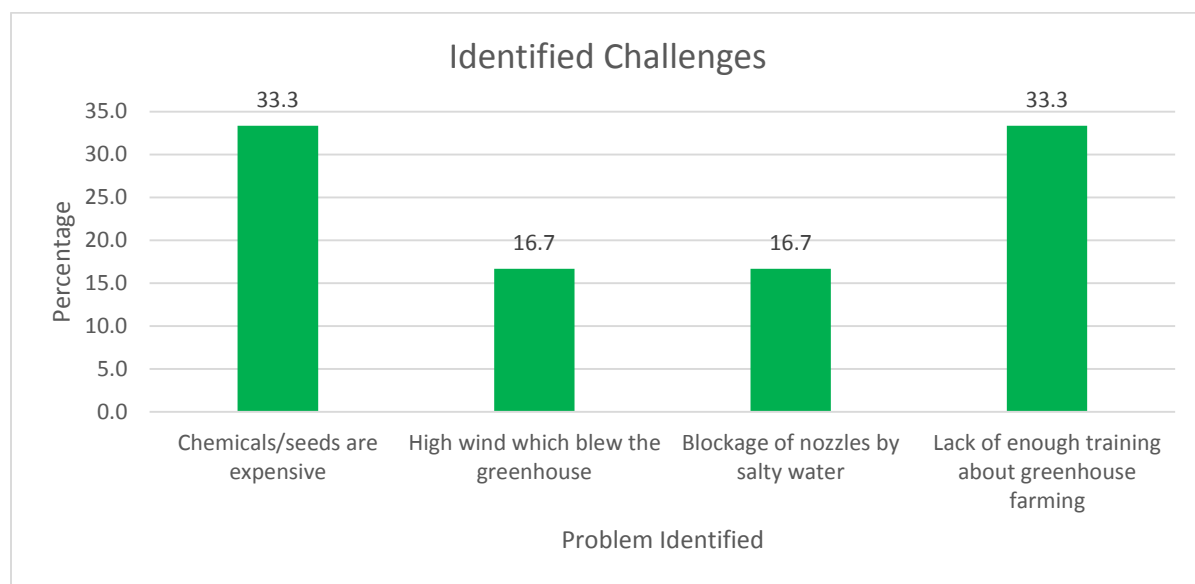


Figure 4.22 Challenges of Greenhouse farmers

Source: field data 2018

From the chart identified, chemicals and seeds were identified as expensive as some farmers pointed out that they had challenges in getting quality seeds (33%). Other challenges mentioned included lack of training about greenhouse farming (33%), and high winds which blew greenhouses. The irrigation systems were also identified to have challenges including blockage of nozzles by salty water, and increasing diseases attacks as rated by 33% of the respondents. There was also lack of generator to pump water from the river to the greenhouses (17%). Other challenges include wrangles within the groups arising from divergent ideas that further wreck the implementation of greenhouse farming. Other members felt that the greenhouse environment was also not conducive especially during the hot days.

### 4.6.3 Rating of challenges

Among the identified challenges, the respondents were asked to rate the challenges based on how they affected them. Figure 4.23 shows the rating of the greenhouse farming challenges;

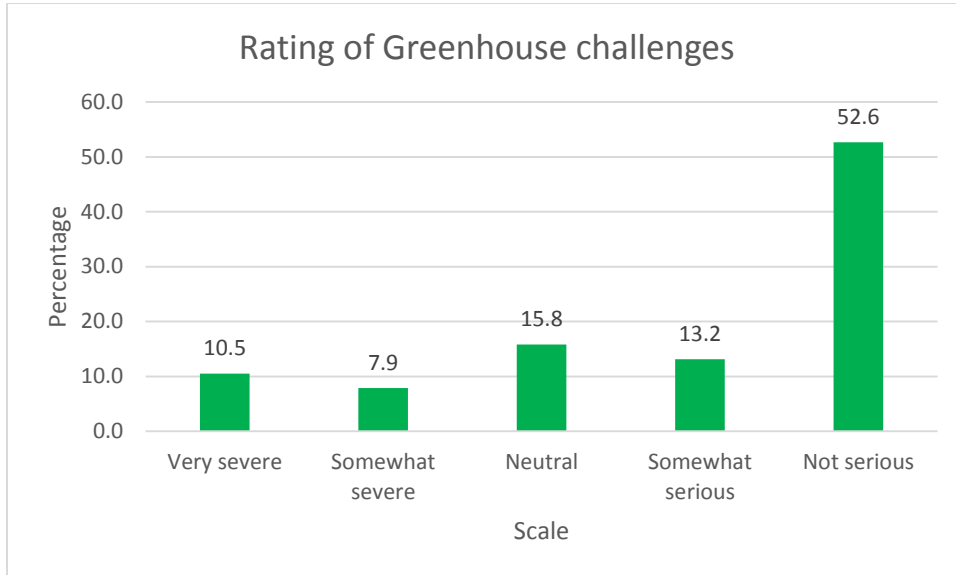


Figure 4.23 Rating of greenhouse challenges

Source: field data 2018

About 18% of the respondents felt that the problems were severe, either somewhat or very severe. It was however felt that most of the problems were not serious as 53% of the respondents supported that the problems were not serious.

## 4.7 PROPOSED SOLUTIONS FOR ADDRESSING THE CHALLENGES

The study had four objectives with the fourth objective seeking to get solutions and recommendations for the challenges identified. The study thus identified the solutions from the farmers, with proposed solutions from the local NGOs and from the Kitui County Government and the National government.

### 4.7.1 Proposed Solutions

About 58% of the respondents felt that there were solutions to the identified while 42% indicated that they could not find solutions to the identified challenges. Table 4.10 shows the summary of responses given on solutions to the challenges identified;

Table 4.10 Solutions to Identified Challenges

<b>Solution</b>	<b>Frequency</b>	<b>Percentage</b>
Greenhouse officers to train farmers on how to maintain farming through greenhouses	7	18.9
Government to subsidize greenhouses	1	2.7
Government to provide chemicals	2	5.4
Provision of water eg boreholes, dams, tanks	9	24.3
For the greenhouse that are supplied with water pumped with electricity KPLC should help in good supply of electricity	1	2.7
Provide generator to pump water from the river to the greenhouse farm	3	8.1
Provide advanced drips like nozzle drips	1	2.7
Provide greenhouse that are conducive in farming in our environment which is hot	1	2.7
Make greenhouse with high quality materials	1	2.7
Dressing polythene paper inside greenhouse to prevent water loss	1	2.7
Intervention of government agencies to address the issue	2	5.4
Market to be readily available to the greenhouse farmers	2	5.4
Desalination of salty water	1	2.7
Greenhouse to have shade net to reduce heat	2	5.4
Output prices to be increased in the markets	1	2.7
Cooperation of members	1	2.7

Source: field data 2018

Some of the suggestions provided by members included providing water (whether from boreholes, dams or from tanks), and having agricultural extension officers training greenhouses farming systems. The table provides further solutions for enhancing efficient greenhouse farming.

#### **4.7.2 Government policies changes to make friendly greenhouse farming**

Farmers also feel that there are possible solutions to the problems facing greenhouse farming. Table 4.11 shows the summary of the solutions provided by the farmers in relation to handling their challenges.

Table 4.11 Government Policies

<b>Solution</b>	<b>Frequency</b>	<b>Percentage</b>
Provide more greenhouses to farmers	10	25.0
Reduce prices of greenhouses	2	5.0
Prices of outputs to be increased	1	2.5
Provide cheaper seedlings	2	5.0
Provide water by constructing dam/borehole	4	10.0
Offer trainings to farmers	9	22.5
Offer grants to low income farmers	1	2.5
Provide better greenhouses	1	2.5
Implement policies that will favor greenhouse farmers in terms of item for exportation	3	7.5
Provide inputs required	1	2.5
Support greenhouse farmers	1	2.5
Lower revenue from greenhouse farmers	2	5.0
Government to employ people to take care of greenhouses	1	2.5
Lower prices of chemicals	1	2.5
Provide market/outlets	1	2.5

Source: field data 2018

It was observed that over 25% of respondents indicated that they could provide more greenhouse to the farmers. There were also 23% of the respondents who felt that trainings to farmers to ensure their capacity and skills are enhanced were recommended. In addition, about 8% of the respondents also indicated that implementing policies in greenhouses farming could improve the performance of greenhouse farming.

## CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

### 5.1 Introduction

The final chapter focuses on summary of the key findings, conclusions and recommendations drawn from the chapter four findings. The study focused on assessing the impact of greenhouse farming on food security at Ikutha region in Kitui County. There were four objectives to be analyzed. They included comparing the productivity before and after greenhouse adoption, comparing income from greenhouse crops before and after greenhouse adoption, and identifying challenges faced by farmers who are embracing greenhouse farming. The chapter also presents conclusion and recommendations needed to improve farmers' productivity especially in Ikutha sub-county and other ASALs regions in Kenya.

### 5.2 Summary of Findings

The section presents the summary of the findings as informed by the information collected and analyzed in chapter four.

#### 5.2.1 Comparison of the farm productivity before and after the greenhouse adoption

On the issue of productivity, there was increase in production when farmers adopted greenhouse farming as compared to when there was no greenhouses. The study concluded that there were significant changes in yields among Ikutha region farmers when comparing before and after adopting greenhouse farming. It was found that when farmers embraced greenhouses they tended to get more income as compared to when there was no greenhouse farming. There were also significant positive changes in yields that were experienced when farmers adopted greenhouse farming. The null hypothesis was that the  $\mu$  yields before greenhouse =  $\mu$  yields after greenhouse). From the observed and calculated t-values and significance values (p values), the p value for tomatoes was 0.002, less than alpha level of 0.05 and therefore the null hypothesis was **rejected**, the two means were not the same.

#### 5.2.2 Comparison of the farmers income before and after greenhouse adoption

The same trend was experienced in income generated for all the two major crops, tomatoes and kales (vegetables) where income after adopting greenhouses increased as compared the period before adopting greenhouses. The changes in income and yields in crops grown under greenhouse lead to significant changes in livelihoods of farmers and hence improving their food security at

long run. The study thus found significant positive changes associated with adoption of greenhouse farming. From the paired samples test, the significance test was found to be 0.012 for tomatoes and thus following the rule of thumb in interpreting the T-test results, (If  $p \text{ value} \leq \alpha$ , then reject  $H_0$ ), the null hypothesis ( $H_0: \mu \text{ income before greenhouse} = \mu \text{ income after greenhouse}$ ) was **rejected**. It was thus concluded that the income generated from tomatoes grown using greenhouses was greater than the income generated from farms that are not using greenhouses.

### **5.2.3 Challenges identified affecting greenhouse farmers in Ikutha region**

The third objective was to identify the challenges associated with greenhouse farmers in Ikutha region and they were identified as lack of water supply, lack of adequate training about greenhouse farming, diseases affecting the greenhouse crops, expensive seeds/chemicals, lack of adequate training on greenhouse farming, and lack of pump water for the greenhouses. The other challenge identified was high winds that blew the greenhouses and blockage of nozzles by the salty waters.

### **5.2.4 Recommendations for the greenhouse adoptions to enhance food security**

The recommendations for the increased adoption of greenhouse adoption included involving agricultural extension officers to train the farmers further on the modalities of installing and managing greenhouses. The Kitui County government and the local NGOs (SASOL, DAI and ADRA) need to collaborate to increase farmers' adoption of greenhouse farming. The Kitui County government and the local NGOs (SASOL, DAI and ADRA) need to provide ways of providing water supplies to the greenhouse farmers. Some of the water technologies the partners can use include having piped waters from the nearby water sources. The other recommendation was for the Kitui County Government to create markets for the agricultural produce from the greenhouse farmers and other farmers to reduce the exploitation by the middlemen.

The solutions suggested included having agricultural extension officers training farmers on greenhouse management and maintenance, government subsidizing prices of greenhouses to allow more farmers to access and install them. Advanced drips like nozzle drips were also suggested to help improve water management in the greenhouses. The other two solutions included providing more water supplies and having a controlled market to minimize price fluctuations in the agricultural produce market.



### **5.3 Conclusion**

The study had 49% female and 51% male respondents as well as majority of them having secondary education at 48%. It was concluded that about 9.5% of the farmers experienced food insecurity. It was also found out that 81% of the farmers had their greenhouses constructed by the sponsoring organizations. About 47.5% of the farmers indicated that the cost of irrigation systems associated with the greenhouses were done by the sponsoring NGO. It was also viewed that most of the greenhouse management trainings were sponsored by the NGOs. Marketing of the local greenhouses was done in the local market. The conclusion of the study was that there were changes in productivity and income for the farmers after adopting greenhouse farming. The study concluded that there was significant changes witnesses after adopting greenhouse farming among the farmers. The study was successful and thus managed to identify the challenges and the solutions likely to improve farm productivity and income changes. The study also found that respondents observed changes in income earned after adopting technology. Over 97% of the respondents were aware that adopting new agricultural technology was associated with increased production.

### **5.4 Recommendations**

From the study findings, the recommendations include;

1. Involving more agricultural extension offices from Kitui County Government to help train greenhouse farmers especially on how to manage and maintain greenhouses.
2. The Kitui County Government and the local NGOs (SASOL, DAI and ADRA) need to improve water supplies for the farmers as it was found that majority of greenhouse farmers had challenges in water supplies.
3. The government (both Kitui County Government and the national government, especially the Ministry of Agriculture) need to create market for the agricultural produce, especially those subsistence farmers who mostly exploited by middlemen leading to reduced incomes that further compromise their food security.

### **5.5 Future Research Gaps**

There were gaps in having adequate records for the farmers especially in yields and income generated from the planted crops. There was need to have follow-up studies to determine whether there are any changes in greenhouse farming among the farmers in Ikutha region. It was also found that farmers were not benefiting as expected from using greenhouse farming and thus studies explicitly on the challenges on greenhouse farming in Ikutha and other ASALs are needed to inform what the government and NGOs interested in farming can do to the farmers within the region.

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**APPENDIX 1: QUESTIONNAIRE**

***Questionnaire to assess impact of greenhouse farming on food security at Ikutha***

<b>County:</b> ..... Sub-County: ..... Location: ..... Sub-location: ..... Village: ..... Enumerator name: .....	<b>Date of interview:</b> ..... Start time: ..... End time: .....
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**A. Profile of the farmer**

- 1. Age; 18-27 years [ ] 28-37 years [ ] 38 and above years [ ]
- 2. What is your Gender? Male [ ] Female [ ]
- 3. Level of education attained
  - Primary [ ]
  - Secondary [ ]
  - Technical and Vocational [ ]
  - University [ ]
  - None [ ]

**B. Food Security**

- 4. Do you practice greenhouse farming? Yes [ ] No [ ]
- 5. Which of the following statements fits the meaning of food security in your opinion?
  - Being self-sufficient of food supply [ ]
  - No hunger or fear of starvation [ ]



Availability of adequate nutritious safe foods [ ]

Don't know [ ]

6. This question is about the food eaten in your household in the last 12 months, since (current month) last year and whether you were able to afford the food you need.

Which of these statements best describes the food eaten in your household?

Enough of the kinds of food I/we want to eat. [ ]

Enough but not always the kind of food we want [ ]

Sometimes not enough to eat [ ]

Often not enough [ ]

No comment [ ]

### **C. Ownership and cost of greenhouse**

7. Who constructed the green houses for farmers in your area?

The sponsoring organization [ ]

Farmer /Self [ ]

8. How much did it cost you to construct green house?

Cost range in Kshs

1,000-49,999 [ ]

50,000-99,999 [ ]

100,000-149,999 [ ]

150,000-199,999 [ ]

200,000-249,999 [ ]

250,000 and above [ ]

9. How much did it cost you to install the irrigation system in your green house?

Cost range in Kshs

1,000-19,999 [ ]

20,000-39,999 [ ]

40,000-59,999 [ ]

60,000-79,999 [ ]

80,000-99,999 [ ]

100,000 and above [ ]

10. How much did it cost you to procure chemicals required for your greenhouse crops?

Cost range in Kshs

1,000-4,999 [ ]

5,000-9,999 [ ]

10,000-14,999 [ ]

15,000-19,999 [ ]

20,000-24,999 [ ]

25,000-29,999 [ ]

30,000 and above [ ]

#### **D. Knowledge of greenhouse farming**

11. Were you trained on how to maintain and manage the green houses? Yes [ ] No [ ]

12. Which of these statements is true about how you acquired your skills to manage green house?

Attended seminars that promote greenhouse farming [ ]

Trained by the greenhouse constructing companies [ ]

Trained by the agricultural extension officers [ ]

Acquired skills through the agricultural shows [ ]

Sourced information from the internet/ books by self [ ]

Other (s) specify.....

13. Do you have the farming skills necessary for cultivation of crops under greenhouses? Yes [ ]  
No [ ]

14. How long have you been practicing greenhouse farming?

Less than a year [ ] 2- 5 years [ ] 6- 9 years [ ] 10 years and above [ ]

15. Which of these statements is true on how you market your crops?

Through a society formed by greenhouse farmers [ ]

Take to the local market and urban market [ ]

Buyers come for the produce in the farm [ ]

Other (s) specify.....

#### **E. Diversification in the greenhouse farming**

16. Which crops do you grow in your greens house?

Tomatoes [ ] Vegetables [ ]

Fruits [ ] Flowers [ ]

All above [ ] Capsicum [ ]

Other(s) specify.....

17. Do you plant variety of crops in your green house? Yes [ ] No [ ]

#### **F: Yields harvested and income earned before and after adoption of greenhouse technology**

(This question is applicable to group farmers and individual farmers)

18. How much Kilograms (Kgs) of the varieties/variety of crops mentioned in question 16 above did you harvest before and after greenhouse adoption?

Year	Tomatoes(Kgs)		Onions(Kgs)		Kales(Kgs)		Passion(Kgs)		Maize(Kgs)	
	Before greenhouse adoption	After greenhouse adoption	After greenhouse adoption	Before greenhouse adoption	After greenhouse adoption	Before greenhouse adoption	After greenhouse adoption	Before greenhouse adoption	After greenhouse adoption	Before greenhouse adoption
2010										
2011										
2012										
2013										
2014										

19. What is your average amount of production in kilograms per hectare?

20. Do you consider greenhouse technology a positive addition to your farming practices?

Yes  No

21. If no, state your reasons for the answer given

.....

.....

.....

22. How much (Kenya shillings) was a kilogram of every variety harvested in question 17?

Year	Tomatoes	Onions	Kales	Capsicum
2010				
2011				
2012				
2013				
2014				

23. How much revenue (Kshs) was earned after selling the surplus?

Year	Tomatoes(Kgs* Kshs)		Onions(Kshs*K gs)		Kales(Kshs*Kg s)		Passion(Kshs*K gs)		capsicum (Kshs*Kgs)	
	Before GH adopti on	After GH adopti on	After GH adopti on	Before GH adopti on	After GH adoptio n	Before GH adopti on	After GH adoptio n	Before GH adopti on	After GH adoptio n	Before GH adoptio n
2010										
2011										
2012										
2013										
2014										
Totals( Kshs)										

24. Has the greenhouse technology affected your income levels positively or negatively?

(Please state a reason for your answer below)

.....  
.....  
.....

25. Do you think the adoption of greenhouse technology will have a positive impact in your earnings in the future? Yes  No

(Please state the reasons for your answer below)

.....  
.....  
.....

**H. Size of green house**

30. What is the size of your land?

Size in acreage 0.1- 0.9  1.0- 1.9  2.0- 2.9  3.0- 3.9  4.0- 4.9  5.0 and above

31. What is the size of your greenhouse farm?

Measurements in Meters 6x15  6x20  6x30  8x15  9x30  other (specify)

.....

32. How many greenhouses do you have on your farm?

1-2 greenhouse  3-4 green houses  5 & above greenhouses

33. What changes are needed in government policies and regulations in order to make them friendly to greenhouse farmers?

- 1.
- 2.
- 3.
- 4.
- 5.

**I. Challenges faced**

26. Have you experienced any challenge in the adoption of greenhouse technology? Yes  No

27. What are these challenges?

- 1.
- 2.
- 3.
- 4.
- 5.
- 6.
- 7.

28. If yes, how can you rate the challenges in a scale of 1-5 where 1 is “very severe” while 5 is “Not serious”

.....  
.....  
.....

29. is there anything being done to address those challenges? Yes  No

If yes, what are these solutions?

.....  
.....  
.....

30. What are some of your suggestions to addressing the issue?

.....  
.....  
.....