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FACTORS AFFECTING THE APPROBATION OF HYDROPONICS FARMING AS A MEANS TO MITIGATE AND ADAPT TO CLIMATE CHANGE AMONGST SMALL SCALE FARMERS, A CASE STUDY OF MERU COUNTY KENYA

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DECLARATION

I, Fredrick Mwenda Mugambi, declare that this thesis is a result of my research investigations and findings. Sources of information other than my own have been acknowledged and a reference list has been appended. This work has not been previously submitted to any other university for award of any type of academic degree.

Signature………………………………..

Oslo, 01.06.2020

DEDICATION

Dedicated to my son Jayden Mutembei Mwenda who had to endure his formative years without the company of his father in the pursuit of higher education in a foreign land.

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ABBREVIATIONS

FAO	Food and Agriculture Organization
KPHC	Kenya Population and Housing Census
NFT	Nutrient Film Technique
GOK	Government of Kenya
MOALF	Ministry of Agriculture Livestock and Fisheries
KNBS	Kenya National Bureau of Statistics
KCIC	Kenya Climate Innovation Center
SRSWOR	Simple Random Sampling without Replacement
SRSWR	Simple Random Sampling with Replacement
FCRS	Fixed Cost Random Sampling
KES	Kenyan Shillings
USD	United states dollar
PVC	Polyvinyl Chloride

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ABSTRACT

The conventional soil based agriculture is one of the areas that have been adversely affected by the effects of climate change in the recent past. To cushion themselves against the challenges, farmers across the world are increasingly embracing hydroponics farming. This study builds on this background to explore the factors that influence the approbation of hydroponics farming in Meru County, Kenya. Kenya's agricultural sector is dominated by small scale farmers, hence the focus of the study to this cadre. Specifically, the study aimed at investigating the different actors involved in hydroponics farming and their impact on the adoption of the hydroponics system. The paper also investigated if the production costs and the access to capital to cater for such costs attract or constrain the farmers from adopting the hydroponics system. Additionally, the study evaluated if the economic returns, the crop yields and the access to market influence the farmers choice of crop to produce and the overall decision of whether or not to adopt hydroponics farming. It also sought to determine the challenges, opportunities and constraints that farmers meet in their adoption or development of hydroponics growing systems in the area. Finally, the paper assesses the extent to which access to water affects the adoption of hydroponics farming in Meru County, Kenya.

The study used primary data collected from hydroponics farmers in Meru County. The data collection was conducted using the survey research method informed by the need to get direct data from the respondents without any intermediate manipulation. In this case, the researcher employed self-administered questionnaires and semi-structured interviews to the sampled farmers primarily to collect numeric and qualitative data. The sample composed of 250 farmers. The questionnaires were administered to the 250 respondents achieving a response rate of 92%. It employed both qualitative and quantitative research methods to collect and analyse the data. Two primary methods of data analysis were used namely content analysis for qualitative data, and SPSS and R-Software for the quantitative data to yield ANOVA tests and variables. The study concluded that the initial cost of operations, the cost of fertilizers and pesticides, initial capital, and access to credit, insufficient water, and lack of proper market for their products are some of the big challenges facing hydroponic farmers in Kenya. The study suggests several interventions to help address the challenges. These includes government advancing credit to farmers, training of the farmers, farmers' collaboration with

stable banks, and growing different high yielding varieties of crops as well as using modern technologies to avoid diseases and pests, and the use of eco-friendly pesticides and fertilizers.

1 INTRODUCTION

The sustained increase in global population implies that countries have to increase their food production to support the increase in demand for food. Although the world continues to embrace technology to help meet the rising global food demand, several factors namely climate change, increased demand for land resources, water and energy hamper the world's efficiency in increasing food production (Godfray et al., 2010). In particular, volatile climatic conditions impair the ability of farmers to optimise their food production, mainly because of the variability of rainfall patterns. Low volumes and length of rain could lead to drought while increased rainfall volumes and duration could cause floods all of which have adverse effects on the crop production. Similarly, changes in temperatures could also impact negatively on the growth and maturity of the crops (Gregory et al., 2005).

Overreliance on rain fed agriculture further increases vulnerability to climate change as variances in rainfall patterns as a result of climate change is likely to have a devastating effect on the production (Kabubo-Mariara and Kabara, 2018). The combination of these factors have impaired the global capacity to meet the demand for food using the traditional methods of food production, thereby providing an incentive to devise more efficient food production and farming methods.

According to Kang, Khan and Ma (2009), food security in the global sphere is contingent to stable and reliable climactic conditions, mainly because these conditions affect water resources. Water is a primary factor in food production. Consequently, a decline in the volume of water available for agriculture impairs the efficiency of the food production process, with the outcome being food insecurity. Agriculture has been a major casualty with huge losses to crops and livestock occasioned by the frequent climate change induced droughts(Kang et al., 2009). These droughts have led to water scarcity posing even a greater threat to the livelihoods of the population whose survival is contingent upon availability of water for irrigation and for consumption by livestock. Kang, Khan and Ma (2009) further note that Kenya has made positive strides in mitigation and putting measures to overcome the negative effects of climate change. This has been achieved through instituting policies and relevant legislations aimed at dealing with the climate change threats and reduction of vulnerability. To effectively combat the adverse effects of climate change, collaboration between the two levels of government is essential. To that end, both the national and county governments have made positive strides with institutional reforms that have enabled easy access to climate change fund financing(Kang et al., 2009). However, Omambia and Ong'are (2019) stresses the vulnerability of Kenya to climate change indicating that various sectors of the Kenyan economy have been adversely affected and this impacts negatively on the country's socio-economic development. They note that in the recent past climate change has caused droughts whose frequency and severity has adversely affected arid and semi-arid areas in Kenya by depleting natural resources. Impaired natural resources in turn lead to a decline in agricultural productivity.

Views presented by (Ong'are and Omambia, 2019) point to the effect that weather variations and climate change-induced droughts are the leading causes of vulnerability and socio economic threats to the Kenyan population (Ong'are and Omambia, 2019). It is, therefore, important to develop means to mitigate these vulnerabilities. To that end, one of the proposed measures is to have a means of crop production that is little affected by the climate change induced droughts and constant weather variation. Hydroponics has been identified as one such solution. Lee (2015) notes that climate change does not impose significant effects on the plants produced under hydroponic system and this makes the system sustainable and reliable for an all year production regardless of the weather conditions. Butler and Oebker (2006) note the fast growth rate of hydroponics farming in agricultural production and intimates that it could be the dominant food production system in future. Van os et.al,(2002) hints on the effectiveness of adopting new technologies to do farming in harsh climates noting that despite Israel having dry and arid climate, it has been highly successful in the production of citrus, bananas, and berries all of which production could have been impossible using conventional farming methods in Israel's climate. Kenya is a developing country that has over the years been unable to ensure adequate agricultural productivity to enhance food security across all the counties, specifically in the rural areas. Therefore, embracing the use of technology in farming would present a major opportunity for Kenya to improve agricultural productivity and ensure food security. Hydroponics farming being one such technology would thus cushion Kenya and Meru County in particular from the adverse consequences of climate change.

1.1 Problem statement

The new climate change realities pose a big threat to agricultural production, thereby threatening global food security, especially in poor and developing countries. To meet the increasing demand for food resulting from the rising population as well as to reduce the negative effects of volatile change in climate, agricultural systems need to become more resilient and thrive in varying weather patterns in order to ensure a more predictable, sustainable and reliable production throughout the year. A denominating feature for developing countries is that the livelihoods of a majority of the population are supported by agriculture. Consequently, as argued by Lipper et al., (2014), increased volatility in rainfall patterns resulting from climate change increases the vulnerability of the world's poor. The Kenyan perspective provides a classic case of the needs to transform agriculture and make it more resilient. For example, Kenya derives 65% of her export earnings from agriculture with a majority of Kenyans deriving their livelihood from agricultural related activities (FAO, 2019). The implication of this dependence is that agriculture contributes to employment, household income, and at the macroeconomic level it adds to the country's Gross Domestic Product (DGP). Despite the growing commercial farming in Kenya, a significant section of the population focuses on agriculture for subsistence. In effect, deterioration in agricultural productivity is likely to be a recipe for social disorder and incentive for increased poverty. FAO further notes that a majority of Kenyan farmers are accustomed to rain-fed farming systems and thus vulnerable to the unpredictability of the dynamic weather patterns occasioned by climate change (FAO, 2019).

These developments show that there is a gap in developing measures to reduce or even eliminate the adverse effects of climate volatility. One way to bridge the gap is to provide clear adaptation approaches aimed at reducing plants exposure to changes in climate and increasing their resilience against the climate change stressors. To that end, there is a need to empower farmers to adapt to new farming techniques through the provision of more resilient resources in the agricultural production process that can minimise their vulnerability to the changing climate. Climate resilient pathways ought to be adopted in a collective approach to mitigate the climate change threats. The proposed solutions are; building resilience, increasing the effectiveness of local institutions, formulating agricultural policies to overcome the adverse effects of climate change, and provision of financial incentives to the farmers with the ultimate objective of increasing the agricultural productivity (Lipper.et.al, 2014). These solutions reflect the elements of climate smart agriculture. The three main objectives of this form of agriculture are reducing carbon emissions to minimum level, sustainably improving agricultural outputs and income flow to the farmers, and adapting agriculture to become more resilient to climate change (Lipper et al., 2014).

The introduction of hydroponics system in agricultural production could be termed as one possible way towards climate smart agriculture in the sense that climate change does not affect output or agricultural efficiency under hydroponic systems, thereby boosting agricultural resilience. It should however be noted that hydroponics system is a costly venture that requires access to capital, the necessary information on operations and market prospects, and a steady supply of the mineral solutions for it to be successfully adopted (Kibiti, 2017).

The yields for hydroponic systems are significantly higher compared to the traditional methods of agriculture. Specifically, Kibiti (2017) contends that production under hydroponics system yields 1000 times more than the conventional farming methods. The Kenyan farmers have mainly embraced hydroponics farming for fodder production to feed their livestock. This is largely informed by the systems shortening of the growth curve as the fodder gets ready for harvesting in 8 days in a sustainable system that guarantees stable fodder production all year round (Njima, 2016). The improved efficiency in fodder production enhances the efficiency of the entire supply chain. This implies that livestock yields such as milk and meat are sustainably supplied throught out the year despite the variability in weather conditions. It is plausible to argue that the same application of hydroponics system used in fodder production can be replicated in other agricultural segments. In Meru County, however, there is a very slow uptake of the hydroponic farming despite some areas being very dry with prolonged drought periods. Studies indicate that only 5% of the Meru farmers embrace hydroponic farming in Meru (Kibiti, 2017). Consequently, Meru County continues to experience persistent deficits in food production, implying that poor households have to rely on government food relief programs. Additionally, commercial farmers from Meru County lack the yields and consistency to become competitive in the food market, eventually impairing their ability to negotiate with major players in food supply chain. The low uptake of hydroponics system despite its numerous benefits in the mitigation of the climate change effects justifies an assessment of the factors that influence the approbation of hydroponics farming system as a means to mitigate the adverse effects of climate change in an effort to help farmers adapt to such changes in the dry and drought prone areas of Meru. A review of these factors coupled with the analysis of any possible shortcomings in the hydroponics farming, could help the government at the national and county level to induce the relevant intervening measures with the objective of enhancing crop production to ensure a more sustainable and predictable means of food security in the wake of the changing climate.

1.2 Rationale

Water is a factor of agricultural production that plays a pivotal role both in commercial agricultural use and in the local farming practices. With rain fed Agriculture and small scale irrigation being a major source of livelihood in Meru county, unpredictable rain patterns, prolonged droughts and drying rivers have all left the Meru county population highly vulnerable to these climate change effects. Hydroponics farming saves water compared to the conventional farming methods while guaranteeing a stable high yielding production throughout the year as it is not affected by weather variability (Kibiti, 2017).

In some types of hydroponic systems water is reused in a closed circuit where it is collected in reservoirs for redistribution within the system (Tripp, 2014). This means that the little water available in Meru County both through reducing volumes of rainfall and drying rivers could be harvested in dams or water pangs and availed to the farmers through piping for hydroponics farming systems. The boreholes currently being constructed by the Meru county government to provide water for domestic use to the residents could also act as a source of water for the hydroponic farming systems since the system use minimal water volumes and thus such diversions could have little or no effect to the volumes available for domestic use.

Meru County is one of the most populous counties in Kenya with a population of 1.5 million people according to the data from the Kenya Population and Housing Census (KPHC) (2013). The fact that Meru County is one of the most populous counties in Kenya coupled with the 2.1% annual growth has two major implications; first agricultural output needs to surpass the growth of the population, and, second, there is a sustainable domestic market for agricultural products within Meru County. The absolute poverty level in Meru County is 15.5%, a level significantly low compared to Kenya's national poverty level of 36.1%. The low poverty level can be attributed to the diversity of streams of income for the households of Meru County (KNBS, 2018). Again this divergent income streams implies the possibility of some of the members within the community having the financial capability to adopt to new food production technologies.

Access to food is a human right and the government has a role to play to protect the right for every person to access food. To that end, it is incumbent on the government to embrace new agricultural technologies and mainstream them in subsistence and commercial farming for farmers within Meru County. Hydroponics system could lower the cost of farming, thereby lowering the price of agricultural outputs in the long run. In effect, the poor population will offer ready market for cheaply produced farm products. The poverty levels will only offer initial cost challenges but will offer a ready market for agricultural products produced within the county.

Most of the research done on hydroponics farming system in Meru county focuses mainly on its use as urban farming to counter the food insecurity that could be occasioned by rural-urban migration and conversion of agricultural land for urban housing.

There too exists some research on the use of hydroponics in Kenya and parts of Meru County for fodder production. However, there still exists a gap in the focus of hydroponics farming system as an approach to mitigate the effects of extreme changes in climate change and adapt the farmers to the new agricultural dynamics. The prolonged drought in many parts of Kenya and by extension to Meru County is making conventional agricultural production both for subsistence and economic use unsustainable (Kabubo-Mariara and Kabara, 2018). This calls for a need to explore farming methods and systems that are resilient to climate change in order to decrease vulnerability to the Meru county population and also ensure food security not only to the local community but also to the larger Kenyan population.

1.3 Purpose of the study

The principal aim of the study was to determine the factors that affect the approbation of hydroponics farming system in Meru County, Kenya. To that end, hydroponics system is viewed as a measure that can help overcome the negative effects of climate change and help small scale farmers in Meru to adapt to new farming techniques.

1.4 Research objectives

The following objectives were used to guide the execution of the study;

1) To investigate if the different actors involved have a role to play in supporting or encouraging the farmers adoption of the hydroponics system.

2) To investigate if the production costs and the access to capital to cater for such costs attract or constrain the farmers from adopting the hydroponics system.

3) To assess if the economic returns, the crop yields and the access to market influence the farmers choice of crop to produce and the overall decision of whether or not to adopt hydroponics growing.

4) To assess the challenges, opportunities and constraints that farmers meet in their adoption or development of hydroponics growing systems in the area.

5) To assess the if and the extent to which access to water affect the advent of hydroponics farming among small scale farmers in Meru County, Kenya.

1.5 Research questions

1. What are the production costs involved in hydroponics in terms of capital input, labour input, construction costs, water costs, nutrient solution costs, fertilizer costs, pesticide costs and how does the ability/access to them influence the adoption of hydroponics growing in the area?

2. How do the yield levels, economic returns, and market factors inform the choice of crop type and farmers morale to further develop or adopt hydroponics system?

3. Who are the actors involved and what kind of services do they extend to the farmers in the development of hydroponics farming?

4. What influenced the farmers to adopt hydroponics, what are their numbers and what challenges, opportunities and constraints have they encountered in the hydroponics farming development?

2. LITERATURE REVIEW

2.1 Introduction

This chapter investigates the existing literature on hydroponics farming system that is relevant to the aims of this study and its guiding research questions. The review starts with a detailed description of the meaning of hydroponics, historical background and the merits and demerits of hydroponics while reviewing past studies with a similar focus in order to build on their findings and the existing research gaps. In this case, the literature review explores how different users and researchers in hydroponic systems have contributed to its improvement by overcoming their originally inherent challenges. This is in line with Bryman's teaching that literature review should involve a detailed analysis and examination of the existing studies on the phenomena under investigation. It ought to incorporate a review of the theoretical approaches employed on the existing studies that could be relevant to the area that a researcher is interested in (Bryman, 2012).

The review further explores the different types of hydroponics system while singling out the one that is relevant for the area of interest in this study. The deduction from this section is that although hydroponics systems have numerous denominating advantages, different systems are suitable to thrive in unique environments. The review was geared towards providing a solid foundation for the study and at the same time point to the relevant concepts and indicators applicable in the case study of Meru County.

2.2 The definition hydroponics

The term hydroponics derived its meaning from two Greek words namely hydro and ponos. Hydro is the Greek word for water whereas ponos is the Greek word for labour. This implies some form of labour being employed on water to constitute work in crop production. Jones (2005) defines hydroponics as a means of growing plants that eliminates the essential need for soil present in other systems of farming. In contrast with the traditional systems of farming where soil contains the required nutrients; hydroponics farming enriches water with the nutritional requirements and that feed the nutrients to the plants. Jones (2005) further contends that in this form of planting, the plants roots are provided with an inert medium for support. Sand or gravel could be used as such inert media.

In agreement with the definition provided by Jones, Sinswar (2012) describes hydroponics as the practice of plant production where soil is eliminated in the production process and another media introduced to hold the plants. The necessary nutrients are introduced through solutions induced in water. He attributes the popularity of hydroponics to its immunity to weather variations, easier elimination of pests and diseases associated with the soil, reduced water costs (Since the closed hydroponic system recycles water), energy and labour savings. He further notes that hydroponics yields better harvest compared to the conventional farming. It's flexibility in terms of areas of application makes it a more reliable means of production and thus increases its production's predictability.

Kibiti (2017) agrees with Sinswar by arguing that a water solution mixed with vital nutrients is used to supply the plant with the requisite nutrients for growth. He further argues that the highly controlled operations culminate in the provision of a well-designed optimal environment for the plants to thrive, hence increasing their productivity as compared to their counterparts produced conventionally.

2.3 Historical background of hydroponics

The use of water enriched nutrients to grow plants is a practice that has been live for many centuries. One of the earliest cases was in Babylon whereby hydroponics farming was in the form of floating gardens, as well as the cases of Aztecs Mexico (Jones, 2005). Steiner asserts that a study carried out in 1800 to investigate the growth of plants established some basic concepts of aquaculture from which the current hydroponics has evolved (Steiner, 1985; Cited in Jones, 2005). Tripp appears to agree to the Babylonian roots of hydroponics farming system by noting that the hanging gardens that existed in Babylon signified the earliest record of the 'use of hydroponic garden'. He adds that the hydroponic technique was also widely used elsewhere in the Aztec and Chinese cultures (Tripp, 2014). The formal studies on the use of hydroponics is said to have started in 17^{th} Century with the publication of the studies by Sir Francis Bacon and John Woodward. Scientists at the university of California at Berkeley brought the concept of hydroponic 'gardening and commercial Agriculture' to the national attention of the United States. The concept was highlighted in the Time magazine way back in 1938 (Tripp, 2014). The denominating feature for these studies is that they started to popularise the idea of growing plants using water solutions as opposed to the traditional method of using soil.

California scientists are credited with the popularization of hydroponics through a series of published studies on 'soilless plant culture' that they carried out in the 1930's (Gericke, 1929, 1937, 1940; Cited in Jones, 2005) The US Army participating in the Second World War engaged in large hydroponic farming spread over many Western Pacific Islands to supply their military personnel operating in the area with fresh vegetables (Eastwood, 1947; Cited in Jones, 2005). Although the application of hydroponics system by the military was incentivised by lack of land for farming, it provided a classic case study on the historical background of hydroponics and the incidental advantages.

The earliest record of soilless terrestrial farming is that of Francis Bacon in his 1627 book entitled The Sylva Sylvarum. Research into water culture gained momentum in the following decades and by the year 1842 scholars had established what was believed to be 9 essential elements for plant growth (Kibiti, 2017). One of the observations of the subsequent research was that less-pure water sources provided the optimal environment for hydroponics farming compared to purified water. Ultimately, researchers coined the phrase solution culture to refer to the growth of plants in mineral nutrients without the use of soil as is the case in traditional agriculture. The work of Francis Bacon set the pace for modern research into hydroponics farming and has over the years become a central theme in agricultural and economic research.

The development of soilless plant growth is credited to the research work of two German Botanists namely Julius Von Sachs and Wilhem Knop (Mowa, 2015; cited in Kibiti, 2017). The solution culture has evolved to be one of the contemporary types of hydroponics that use inert medium in plant production. Hydroponic system enables easy monitoring of plant nutrient absorption, how the plants develop physiologically and general root Morphology (Kibiti, 2017). The outcome is the creation of a holistic plan development process whereby plants grow to yield the expected nutrients.

In Kenya, hydroponics is gaining traction especially in the production of fodder to feed livestock amongst small and medium scale farmers. The fodder growth span in hydroponics is shortened to only 8 days thus enabling the farmers to enjoy an uninterrupted supply of fodder all year round. A space of 20 feet by 10 feet gives the farmers a production of over 50 Kilograms of fodder (Ayele et al., 2012). Studies reveal that farmers could produce up to 1.2 tons of fodder with only 700-900 litres of water in a 140 square meters of a hydroponic greenhouse. Barley, Wheat, Maize and oats have been cited as the preference cultivation crops for most of the farmers who embrace hydroponics. Barley has more protein nutrients that are highly effective in increasing livestock production thus making it highly preferred by most farmers.

Commercialization of hydroponics farming has been established having gained momentum from the 1980's mainly focused on the production of commercial vegetable (Elliot, 1989; Cited in Jones, 2005) and commercial flower production (Fynn and Endres, 1994; Cited in Jones, 2005). Jensen predicts an increase in the greenhouse acreage under hydroponics farming techniques noting that the current global acreage of greenhouse hydroponic vegetable production is 60,000 acres (Jensen 1995; Cited in Jones, 2005). However, it is worth noting that most hydroponics production is done in vertical layers for maximum land utilization and this could have made the global acreage under hydroponics appear small. If the vertical layering was to be eliminated maybe this acreage could have increased significantly as this could have expanded the area under production. The figure below depicts a possible vertical layering of hydroponics fodder production.

Author, 2020

Figure 2. 1 Vertical layering of hydroponic fodder production

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Jones (2005) notes a considerable adoption of Hydroponics technique in Canada, Mexico and the United states with Tomato being the most preferred for production followed by Pepper and cucumber at 68%, 17%, and 15% respectively based on a 2004 hydroponics merchants association publication.

2.4 Merits and demerits of hydroponics

The growing global popularity of hydroponics farming could be attributed to the numerous advantages that hydroponics have over the conventional methods of planting in soil. One such advantage is that hydroponics is suitable even in areas where the soil is not conducive for conventional farming for it eliminates the use of soil which means that it is possible to grow plants even in areas with mineral deficiencies to support plant growth, or even in areas where the soil has been infested with diseases that could hinder conventional growing methods. Hydroponics highly saves on labor cost as it eliminates the traditional practices that were labor intensive such as cultivation, fumigation, watering and tilling (Tripp, 2014).

The labor cost savings have major economic implications. First, for farmers who have embraced hydroponics farming for commercial farming, reducing labor costs improves their profit margins. Second, in the case of subsistence farming, labor cost savings improves the disposable income for households. These factors culminate in improved micro and macro-economic dynamics in countries where there is extensive application of hydroponics farming systems. Its ability to plant in layers saves on land thus making it economically feasible even in cities where land is normally expensive. This layering ensures maximum production on small areas of land. The system conserves water and nutrients and this minimizes the pollution of the surrounding land and rivers as most of the water, nutrients and chemicals used in the system mainly end up being utilized within the system with very little or no discharge to the surrounding environment (Jones, 2005). The decline in pollution emanating from the use of hydroponics systems is in tandem with the global efforts to reduce carbon emission from farming activities.

Wignarajah credits hydroponics farming over planting in soil noting that it makes all the supplied nutrients ‘readily available to the plants’. He further notes that it is possible to optimize the plants ability to absorb nutrients by controlling the PH level of the nutrient solution. He teaches that leaching is eliminated under hydroponics and thus eliminating nutrients loss that such leaching could have occasioned (Wignarajah 1995; Cited in Jones, 2005). These factors improve the efficiency of the farming process by reducing the uncertainty inherent to the traditional soil domiciled farming concerning nutrients requirement by plants.

Tripp credits crops grown hydroponically for their high nutritional value owing to their utilization of 'naturally occurring nutrients'. He further notes that such high nutritional value could be attributed to the fact that 'no pesticides or other chemical agents' is used in the production of crops done hydroponically (Tripp, 2014).

In most cases, the production by hydroponics doubled, tripled or even increased tenfold compared to the production by open agriculture. This is the biggest advantage of the use of hydroponics and means of crop production (Tripp, 2014). However, in spite of the above advantages, some shortcomings have been noted in hydroponics techniques. One such shortcoming has been noted by Wignarajah who hints that, a decline in the level of oxygen tension in the nutrient solution would inhibit ion uptake through the creation of an anoxic condition. He claims that having a system that could supply oxygen directly into the roots as it is the case in aeroponics could eliminate the problem (Wignarajah, 1995; cited in Jones, 2005).

2.4.1 High initial cost

The initial cost for hydroponics systems consists mainly of the cost of setting the system. The high cost has been noted as a major drawback to the production of crops hydroponically. Besides the initial set up costs, hydroponics systems are associated with additional overhead costs that are not present in the conventional farming methods. Such overheads include the lighting, heating, the cost of buying/producing the nutrient solutions, and pumps that run the system. All this makes commercial hydroponics farming system a costly affair (Tripp, 2014). The smallest hydroponic structure should accommodate at least forty large plants and a minimum of 72 small plants. Inside the greenhouse structure should be an Arduino climate control monitoring system that monitors the light intensity, temperature, humidity and carbon dioxide concentration. All these are generally expensive, only the structures can be made from readily available materials such as wood and PVC sheets. Availability of the system and transportation costs as well as labor costs is another set of costs that inflate the initial expenses. A medium sized hydroponic greenhouse costs between 500 and 2000 US dollars

(Takaruka, 2014). Consequently, hydroponics system may not be available for use by poor households in urban areas where farming would primarily be geared towards subsistence farming. Equally critical is the view that hydroponics systems in commercial farming require a farmer to generate significant cash flows to justify or recoup the initial investment cost.

2.4.2 High maintenance and running cost

Hydroponics greenhouse works within narrow and precise temperature range to enhance optimal production. In addition, the large concentration of nutrients that must be maintained in the water as well as the energy used for pumping, running exhaust fans and sensors are other regular expenses that must be incurred. High management skills are also critical to the successful production using hydroponics, this may led to employment of farm technicians and managers who could as well be paid.

Tripp (2014) points to the possibility of contamination arguing that the systems have a wide range of risk factors. He notes that the water used in the system, the substrates that replace the soil as roots holding medium, containers and troughs used for planting, the tubes and other nutrients delivery systems are all susceptible to contamination and thus the system requires a very high vigilance and sanitation to avoid a catastrophic outcome.

Another challenge of the hydroponic system is the technical expertise required for a smooth operation of the system. An optimal growth of plants requires a complex mixture of macro and micro nutrients that are found in the soil. With the system eliminating the use of soil, all these nutrients need to be properly mixed and supplied to the plant through the nutrient solution in the right proportions all of which call for a highly efficient and technically trained personnel (Tripp, 2014). Tripp adds that even in the circumstance where one buys the nutrients ready-made, the technical expertise is still required to know the right proportions to mix. He further notes that different formulas are applicable in the growth of vegetables, fruits and flowers a factor that further complicates the system as the farmer needs to be well conversant with all these formulas if he or she has to be successful in the production of these crops hydroponically.

Temperature and humidity control has also been cited as a major challenge in hydroponic farming system. Consistency in the temperature and humidity control is highly encouraged to avoid a compromise of the whole growing system. A sudden increase or decrease of the two could greatly affect the optimal growth of the crop. For an optimal performance of the crops, the ideal temperature should range between 60-90 degrees Fahrenheit (approximately 18-30 degrees Celsius) and the humidity of the growing environment should be between 50-60% (Tripp, 2014). A regular maintenance of these conditions could prove to be a daunting task to the farmer and thus could call for specialized systems which further pushes the production costs up.

2.4.3 Hydroponic techniques

There are two basic hydroponics techniques that can be modified depending on the available systems and resources. The two techniques are the solution culture and the media culture methods (Khan et al., 2018). The two techniques differ widely in their water saving properties, fertilizer use efficiency and productivity.

2.5 Solution culture technique

Maharana and Koul (2011) refers to solution culture as liquid hydroponics based on the rationale that such culture is crucial in supporting the growth and development of plants grown hydroponically. Specifically, the plants roots are suspended directly in the nutrient enriched solution. There are three categories of this mode of hydroponics namely the aeroponics system, the static and continuous flow solution cultures. The continuous flow solution culture technique involves a pump that circulates the nutrient solution in plant roots and the excess solution is collected at the end for reuse. This system can adopt the nutrient film or the deep flow techniques.

2.6 Static solution culture

The major defining feature of this method is that the nutrient solution is provided at once when the EC changes and not being circulated. The three categories of this method are the floating method, root dipping method, and capillary action method. Rood dipping includes the plants being grown in pots containing the growing media and the lowest part of the pot being dipped in the nutrient solution. In the floating method, shallow containers filled with nutrient solution are used to grow the plants and the pots are fixed on Styrofoam sheets which are floated on the nutrient solution. The capillarity action technique involves seeds being planted in pots filled with inert medium. Shallow containers with nutrient solutions are then placed in the pots and the nutrients reach the plant roots by capillarity action (Khan et al., 2018).

2.7 The aeroponics systems

The system is defined by the growth of plants by anchoring them in hole on Styrofoam panels. The roots are thus suspended in the space underneath the panel. This technique is most appropriate for lighter plans with less leaves such as spinach and lettuce.

2.8 Types of hydroponics system

While making a case on the versatility of the hydroponics system, Tripp (2014) notes that there is a growing system to suit every need. He outlines the most common types as the basic wick system, Earth tainers, the raft system, top feed drip system, and the nutrient film technique.

2.8.1 The basic wick system

It is the most basic of all hydroponic farming systems. Mostly utilizes troughs and flowerbeds. According to Tripp (2014), recycled containers such as soda bottles or water gallons can be used to hold the plants. Under this system, the wick is used to draw the minerals into the substrate. The system is most suitable for plants that utilize low volumes of water and minerals for optimal growth.

2.8.2 Earth tainers

The system consists of a container with a ‘built in trellis, a wicking basket and an inbuilt air gap that allows any overflowing water back into the system through a filing tube. Tripp (2014) contends that the system is spacious enough to accommodate a potting mix. It is ideal for plants that need a deep base and support system such as the tomatoes and peas.

2.8.3 The raft system

In this system, aerated water is used and a foam raft type device used to support plants that floats in the nutrient solution contained in a basin. According to Tripp (2014), the raft can be made out of an aquarium or a container that is water tight making the system most suitable for ‘in-home growing’.

2.8.4 Top feed drip system

This is a bucket system with tubes that channel water to the plant tops. A timer is inbuilt to control water and nutrients supply to the plants base. It is most suitable for plants that do not have an established 'solid root system'.

The drip system can be used as a recovery system where the excess nutrients and water are channelled to a reservoir for redistribution back to the system or non-recovery drip system that do not 'collect run-off water' but make use of precise timers that ensure plants receive sufficient nutrients at 'precise times'(Tripp, 2014). The figure below illustrates how this system has been adopted and practised in the study area.

Author, 2020

Figure 2. 2 A photo illustrating a drip hydroponic system in Meru County

2.8.5 The nutrient film technique

The technique is also referred to as the NFT technique. Here the pipes are arranged in a sloping manner with water being pumped from the upper arc of the system and flows downwards. Plants are placed on top of the slanting tubes and this allows the minerals to flow down the root system from the water rich mineral solution (Tripp, 2014). It is the most common technique for commercial farming systems.

The commonly used hydroponics system in Kenya is the one that use nutrient film technique aimed at maintaining a ‘thin film of nutrient water’ that runs through PVC pipes that are arranged horizontally. There is a water reservoir that collects the water from the system. This water can be recycled back into the system either manually or by use of a simple electric pump that pumps it back to an elevated water storage system.(Miramar international college, 2019)

The hydroponics system can also be used to grow high value, short period maturing fodder. The fodder is grown in a room with controlled and regulated temperature and humidity. Photo-chemically treated trays are used to grow grains which are sprayed at ‘predetermined intervals’ with nutrient solutions. This system can be said to be cost effective as it utilizes both a hydro-net and hydro-cloth to control the temperatures and humidity inside the system thus eliminating completely the use of electricity. The fodder takes seven days to be ready for harvesting (Fodder systems,2019).

The figure below shows a photo of the nutrient film technique used in the study area.

Author, 2020

Figure 2. 3 A photo of the nutrient film technique adopted by hydroponics farmers in Meru County.

2.8.6 Factors influencing hydroponics farming in Kenya

One of the factors that favor hydroponics cultivation in Kenya is the limited high potential agricultural land. Specifically, only about 17% of Kenya's land is ideal for agricultural productivity, with the rest of the land being arid or semi-arid. It is also critical to note that the 17% section of land is further divided into livestock farming and intensive crop farming, implying that there is limited agricultural land for traditional farming methods that are soil intensive (FAO, 2019). Consequently, the primary course to increase agricultural productivity is to optimize the use of the existing section of land, or by exploring methods that would be ideal in arid and semi-arid areas. The dependence on rain fed agricultural production is largely vulnerable to weather changes thus affecting production and income. In addition, the measures put by the government to promote are inadequate because they have not been implemented across the country.

The two factors namely the low fraction of productive land and reliance on rain fed agriculture are incentives for increased uptake of hydroponics system of farming. In the first case, the 17% of land available for productive agriculture is constrained by the increasing population such that the agriculture productivity per unit of land is declining. Further, there is a need to improve the output for the existing fraction of land available for agriculture. Embracing hydroponics system would help to overcome these challenges by increasing the productivity of the existing agricultural land. With respect to the second aspect of overreliance on raid-fed agriculture, hydroponics system would be useful in ensuring even agricultural production across different seasons of the year.

In an effort to determine the factors responsible for the uptake of hydroponics systems in Meru County of Kenya, Kibiti (2017) conducted a mixed methods study that targeted 1,080 urban farmers that practice hydroponics farming in Meru County. A critical observation from the study was that the availability of water for irrigation greatly determined their ability to produce throughout the seasons and benefit from the high output prices especially in dry seasons. Water is an essential factor of production in agriculture. Therefore, the availability of water in Meru County coupled with the county government's effort to establish the infrastructure for water storage provides an optimal environment for the practice of hydroponics farming in Meru County.

The type of crop is another major factor influencing the adoption of hydroponic farming in Meru County. It was noted that this determined the income levels from the farming as different crops take different durations to mature. Most farmers in the area practice farming on a small scale with limited capital available for initial investment and subsequent cost of maintenance. Implied in this situation is that hydroponics systems in Meru County are best suited to maximise yields for crop with short maturity durations. The short turnaround helps farmers to recoup their investments in a short duration, thereby allowing continuity of farming. In this case, the observation by Kibiti (2017) is that farmers in this case preferred high yielding short duration maturing crops to maximise on their income.

Kibiti found out that access to capital played a major role in the farmer's choice of hydroponic farming system. On this he notes that access to capital does not only ease the financial constraints on the farmer but also boosts his productivity by enabling him have the capacity to adopt new technologies in farming. He also noted that access to capital enables the farmer afford high yielding crops, essential farm inputs such as fertilizers and herbicides and also enable farmers minimize crop loss through theft by enabling them install fences on their farms (Kibiti, 2017). However, access to agricultural sector financing activities especially for large sums of money pose a major challenge to the establishment of hydroponics cultivation. The country has no elaborate programs to offer credit to small scale farmers and this has affected the type of technology used in farms. There are though credit facilities such as Agricultural Finance Corporation but the credit tendered has continued to diminish with time and actual investment in agricultural technology has been small.

Kibiti further notes that farmer's awareness also does affect farmer's decision to adopt hydroponic farming system. He contends that many farmers who adopted hydroponic farming had a quest for information. He noted that they mostly acquired such information from their peers and non-governmental institutions (Kibiti, 2017). The agricultural extension services are critical for hydroponics production because it involves the application of technology. These services play a role in transmitting relevant information while linking the farmers to the market and other external economy. There is however inadequate access to auxiliary services such that the extension officer to farmer ration being 1:1,500. The hallmark effect of these inadequacies is that they handicap farmers from keeping pace with technological changes.

In a related quantitative study carried out to establish the factors influencing the adoption of hydroponics fodder farming in Kiambu County by Njima, it was established that the population demographics factors that included the farmer's age, their level of education, their gender and their farming experience all had a positive correlation with the hydroponic fodder production. Other factors cited in the study has having a positive correlation with the hydroponic fodder production in the area included; management practices, marketing factors, extension services and access to credit (Njima, 2016). People with educational background in agriculture are more likely to embrace hydroponics farming. Similarly, people with more advanced managerial skills and training are more likely to venture and succeed in hydroponics farming.

2.9 Adaptive factors of Meru County

A number of environmental factors affect hydroponics greenhouse cultivation. These factors range from temperature, humidity, carbon dioxide concentration and light. When these factors are too high or too low, the hydroponics greenhouse cultivation is adversely affected.

Studies have shown that low light intensity affects crop production; for instance, when the daylight is low or sub-optimal, then greenhouse yield becomes low, especially in terms of fruit production. Temperature on the other hand also affects production; in tomatoes for instance, lower temperatures result in less juicy and less meaty fruits (Khan, et al., 2018). Additionally, high temperatures lead to change in shape, colour and texture of the fruits in tomatoes, cucumber and eggplant. Air humidity is the most difficult factor to control in a greenhouse but it has drastic effect on crop production. A vapour pressure deficit range 0.2 to 1.0kPa has no effect on the crop growth and development. However, lower vapour pressure deficit in a hydroponics greenhouse leads to a reduction in the weight of fruits. Increasing vapour pressure from 1.0 to 2.5kPa in a hydroponic greenhouse lowers the accumulation of juice in the fruits. Higher humidity in vegetables favours the spread of disease pathogens. Carbon dioxide concentration in a hydroponics greenhouse has an effect on dry weight of plant, height of the plant, the number of leaves in the plant and lateral growth of the plant. Basically, these attributes result from an increased carbon dioxide concentration.

The Meru County's fertile soils and favorable environmental conditions ensure a high agricultural production. However, floods and high temperatures poise threat to all types of agricultural productivity in the region. Other factors that may affect crop production in Meru include high input risks, conflicts between communities and poor marketing systems of agricultural produce. On the contrary, the region has well-managed off-farm services. These include agricultural extension and training, credit and insurance schemes provided to farmers that help increase their capacity. These services are offered by government bodies, private institutions and non-governmental organizations. It is however worth emphasizing that the county lacks specific legislation to support hydroponics greenhouse cultivation. Agricultural production in the region also suffers lack of political goodwill as well as lack of coordination monitoring and implementation mechanisms (GOK, 2013).

Besides the significantly high population of 1.5 million people and the 2.1% growth rate in Meru County, it is important to observe that the number of households connected to electricity in 2013 represented only close to 13.6% and the literacy levels in the county was 53%, a percentage lower than the national rate of 72% (MoALF, 2016). The large population in the county offers ready market for agricultural products produced within the county. Further, the county government has opportunity to embrace hydroponics farming and create employment for skilled and unskilled labour. Employment opportunities will emanate from the actual farming as well as across the supply chain and the distribution of agricultural products. However, the poverty index within the county may pose a number of challenges in the adoption of modern agricultural technology in crop production.

The availability of ready market in Meru County is another factor that plays a major role in favouring agricultural production in the county. Hydroponics crop production cannot be used for producing any type of crops. Owing to its high initial cost of investment coupled with the subsequent cost of maintenance, hydroponics systems are most suitable for commercial farming. Also, not all crops are suitable for hydroponics farming primarily because of the specific needs of the individual crop plants. According to Singh and Singh (2012), hydroponics can be used effectively in producing cereals, fruits, vegetables, fodder, flowers, medicinal plants and condiments. These crops have significant commercial viability, thereby providing headroom to scale farming operations to capitalise on the economies of scale.

3 RESEARCH METHODOLOGY

3.1 Introduction

A research Method could be referred to as the procedures and techniques used in collecting and analysing information concerning a topic. There are two primary concepts involved in the selection of research methods namely validity and reliability. Validity may be referred to as the extent in which the research design and the research methods measure the variables which are essential in the study. Reliability could be termed as the extent in which the research methods, design or the entire study can be replicated. These two elements are essential in the selection of a research methodology. Bryman argues for the need to outline and have a thick description of all the methods, instruments and procedures employed in a study to ensure that the study can be replicated in the future (reliable) (Bryman, 2012). This enhances the reliability and credibility of the study. This chapter discussed the study's research methodology, the underlying theoretical framework, a detailed analysis of the area of study, and the sampling criteria. It also touches on the ethical considerations made and the issues of reliability that were involved in the study.

3.2 Research design

- Research design implies the strategy selected by a researcher that enables him/her to integrate all the components of the study in an effective manner that would allow him to effectively and adequately address of the research problem. According to Žukauskas, Jolita, and Regina (2018) the research design involves all the processes and procedures as well as all the methods used in collecting, measuring, and analyzing data in a study. The following research designs have been predominantly used by both qualitative and quantitative researchers.
- Cohort design,
- Exploratory design,
- Action research design,
- Philosophical design,
- Case study design,
- Observational design in addition to many others.

The choice of the design to be used in a study is usually dictated by the research problems, the research hypotheses, available literature and the type and size of data involved. Palinkas et al. (2013) adds that the design to be used is also determined by the type of the descriptive methods to be employed in accepting or annulling the hypotheses.

This study employs a descriptive research design which adopts cross-sectional methods because it is used to accurately and systematically describe the phenomenon at a particular time. This type of design answers the what, when, where, when and how questions. It also has the capacity to utilize both qualitative and quantitative approaches thus fitting our mixed methodology. Descriptive design does not allow for controlling or manipulating variables as in the case of experimental research but only observes and measures the variables. Basically, descriptive design is used appropriately when the aim of the research is to identify the correlations, categories, frequencies, characteristics and trends. Considering the following research questions;

- ✓ What are the production costs involved in hydroponics in terms of capital input, labour input, construction costs, water costs, nutrient solution costs, fertilizer costs, pesticide costs and how does the ability/access to them influence the adoption of hydroponics growing in the area?
- ✓ How do the yield levels, economic returns, and Market factors inform the choice of crop type and farmers morale to further develop or adopt hydroponic s system?
- ✓ Who are the actors involved and what kind of services do they extend to the farmers in the development of Hydroponics farming?
- ✓ What influenced the farmers to adopt hydroponics, what are their numbers and what challenges, opportunities and constraints have they encountered in the hydroponics farming development?

All the above questions are either what, who or how questions which can be adequately answered through descriptive design of research; thus its choice for the present study. Cross-sectional methods involve a study that takes place at a simple point in time. It likewise does not involve alteration of variables and is applicable in studying the prevailing characteristics of a given population, thus providing information about the current happenings in the population. This is in tandem with the aim of our current study which was to establish the factors that influenced the adoption of hydroponics farming system as a means to mitigate and adapt to the threats and challenges associated with climate change amongst the small scale farmers in the study population. Cross-sectional design is likewise inexpensive because data is only collected once and the span of study is short. It also offers information regarding different variables within a single study and because it offers information with regard to a particular time, it offers opportunities for further studies regarding the study topic or related topics. However, this design may not adequately offer explanations regarding the cause and effect relationships. Therefore, a combination of descriptive and cross-sectional approach would help solve some of the demerits of one or the other.

3.3 Research methodology

Research methodology is termed as the process used in carrying out a research(Bryman, 2012). It guides the researcher on the procedures of achieving the study objectives and answering the problem statement under probe. It interrogates the choice of methods over their alternatives to ensure that the findings of the said study can be evaluated (Berg and Lune, 2012). The ideal research method for a study primarily depends on the nature of the research questions and the aim of the study. Bryman (2012) notes that some research methods are more suitable to answer qualitative research questions whereas other research methods are more suitable in resolving quantitative research questions.

Both a qualitative and quantitative analysis was found suitable for this study based on the study's objectives and it's corresponding guiding research questions employed. Consequently, the study employed a mixed method research approach that broadly employs a mixture of both qualitative and quantitative research designs in its execution. In this case, the mixed methods approach was critical in gathering empirical data in line to best address the objectives of the study and embrace the diversity in the research questions. Some of the research questions best fitted under qualitative method while others were found to be better answered by a quantitative approach.

The combination of the two research designs (i.e. qualitative and quantitative methods) is superior to the application of one of these two methods, thereby solidifying the decision to use the mixed method. Specifically, the mixed method is useful in the analysis of people to the social world because the dynamics of the relationship involves both qualitative and quantitative attributes. Again, qualitative method needs a valid conceptual grounding while qualitative methods are simply important in understanding a social phenomenon (Bryman, 2012). Qualitative methods strive to explore how there is a relationship between variables as well as explore the rationale for such a relationship (why). On the other hand, quantitative methods analyse the frequency of the relationship between variables by exploring two primary elements of how often and how many. In light of the preceding value of qualitative and quantitative research methods, it is evident that a mix of the two methods valuable in gaining insight into the qualitative and quantitative aspects of research variables. It is also important to note that a mixed method allows the researcher to get more information concerning the responses by contextualizing the responses issued by the respondents in a qualitative analysis. This quality enables a more comprehensive quantitative analysis. Qualitative analysis offers may not be as rigorous as quantitative analysis and as Lillis (1999) explains; papers reporting qualitatively are limited in their disclosure of the underlying research design, hence it is important to supplement the study using quantitative research methods. Finally, there is a greater unanimity on the quality of quantitative research methods because it is possible to evaluate the underlying research methods systematically. The hallmark conclusion is that a mixed approach would produce results that are generally acceptable across the divide of researchers.

3.4 Quantitative research method

Quantitative research approaches are premised on the tenets of objective theories. In this case, the pivotal rationale of using quantitative research methods is to explore the existence of a relationship between endogenous and the exogenous variables to confirm whether the underlying relationship conforms to the applicable objective theory. The ideal course is to measure the variables to produce numbered data that can be subjected to statistical procedures for analysis in order to deduce meaningful conclusions (Creswell and Creswell, 2018). A critical observation from the procedures of quantitative methods is that they aim to reduce the impact of individual judgement and emphasise the application of already existing theories. This makes a study reliable because the results can be generalized and the underlying methods can be replicated to produce similar conclusions.

This study aimed at finding out the factors that influence the adoption of hydroponics farming systems amongst small and medium scale farmers in Meru County. A quantitative approach was deemed more appropriate in establishing the various variables influence on the adoption of hydroponics system. Such variables are availability of water for irrigation, capital accessibility, the influence of farmers awareness, and the influence of crop type all of which could be quantified numerically to produce numbered data for statistical analysis in line with Creswell's teaching (Creswell and Creswell, 2018).

Bryman (2012) hails quantitative research as a dominant approach to conducting social research. He further notes that quantitative research capitalizes on the process of quantifying data both at the collection and analysis stage.

The study applied the survey research in which self-administered questionnaires and semi-structured interviews were used to collect numeric data from a sample of the Meru county population with the intent of generalizing such sample to the entire population within the area as taught by Fowler (Fowler, 2014). The semi-structured interviews were meant to meet the objectives of the qualitative method wince the study mixed both a qualitative and quantitative approach in its data collection. Creswell underscores the importance of survey research by noting that it captures a sample data in numerical or quantitative manner that aids in the determination of trends, perceptions and viewpoints of the population under study (Creswell & Creswell, 2018). Such trends, perceptions and viewpoints will inform their interaction with the dependent variables as the research will focus on getting the respondents viewpoint on how these variables influence their choice, on whether to adopt the hydroponic farming system or not, thus making the quantitative research perspective appropriate for adding to the qualitative findings of the study.

The quantitative method was used in the research by taking the descriptive design because of its high reliability.

3.5 Data collection (Quantitative method)

3.5.1 Self-administered questionnaires

The questionnaire involved use of standardised questions to avoid biases. Asking questions is one of the major ways of collecting data for analysis (Fowler, 2014). The study sought to capitalize on the answers obtained from the self-administered questionnaire as its primary data for analysis. The use of primary data has several advantages including the high control level, better accuracy, and up-to-date information. Further, the direct contact with the respondents gives the researcher the opportunity to contextualize the answers for improved reliability. Ultimately, primary data grants the researcher direct ownership over the information provided through the questionnaires.

The questionnaires were distributed to the target group and collected later. This is in line with Singh teaching that most questionnaires are self-administered as they give the respondents' time to read and fill them out and all what the researcher needs to do is to arrange for their delivery and pick-up (Singh, 2007). The other advantage of using this method is that it avoids undue influence on the respondents such that the responses are truthful and accurate. The method also provides time for the respondents to recollect their memories on some of the questions to which they may not have direct or immediate answers. However, the data collection assistants distributing the questionnaires were available to clarify whatever was not clear to the respondents as the researcher had conducted a prior training to them on the content of the questionnaire.

Up to 250 questionnaires were prepared and distributed to the target group. Out of these 230 questionnaires were collected back. This was a 92% response rate which was considered sufficient for the study since Bryman terms a response rate of over 85% as excellent (Bryman, 2012). A high response rate can be attributed to a high level of motivation among the respondents or an extensive personal interest of the respondents towards the subject. In the light of these two factors, the response rate of 92% shows that the respondents were motivated to answer the questions and that they have a personal interest in the issue of hydroponics farming in Meru County. Several measures were taken to achieve such a high response rate. The researcher sought the help of data collection assistants and locals with an expansive knowledge of the target area to administer the questionnaires. A team of five data collection assistants were trained on how to administer the questionnaires and a quick mapping of the area was done with each clerk being assigned to his area. The researcher and the data collection team relied mostly on the commercial motor cyclists (locally referred to as bodaboda) to ferry them to the farmers in the area as they were found to have an extensive knowledge of the area. Most of the farmers were willing to answer to the self-administered questionnaires promptly and this greatly contributed to the high response rate.

Having locals on board as data collection assistants greatly contributed to the positive response rate as the farmers knew them and were more comfortable in welcoming them to their farms. In designing the questionnaires, the researcher deliberately made them have clear instructions and an attractive layout. Questions were simplified and an attempt was made at keeping them short. This is in line with Bryman's teaching that such an approach does not only improve the response rate but also helps in ensuring that the questionnaire does not look unnecessarily bulky to the respondents (Bryman, 2012).

3.6 The data analysis

The quantitative data, being numeric, was then analysed through data analysis techniques that include regression analysis. The SPSS statistical software was employed in the analysis of quantitative data and the variables obtained were processed by the use of ANOVA tests to determine the significant differences between the variables. SPSS software was used to encode data in order to analyse the questionnaire-based data to come up with frequencies and rations relevant to the desired themes. The study applied a multivariate regression analysis. The dependent variable was the approbation of hydroponics farming while the independent variables were the farmers' awareness levels, the type of crops grown, availability of water and mineral solution, crop diseases and pests, and the initial cost of construction. This allowed the researcher to predict the impact of for instance the poverty levels of the participants with their ability to set-up hydroponic farms. Regression is useful in estimating the relationship between variables in a study. Qualitative study would only answer the question of whether poverty/cost of installation of hydroponics affects the farmers' ability to set up the project; quantitative study on the other hand allowed for the comparison of the degree of poverty and the ability to set up hydroponics farms. Additionally, regression analysis helps the researcher to establish the type of correlation between variables; whether negative or positive.

The findings from a quantitative study can be easily used to generalize the concepts more widely as well as predict the future and the causal effects in the relationships established. Therefore, the involvement of the quantitative methods in the study was necessary as it enriched the qualitative findings making the results more reliable and valid.

3.6.1 Data interpretation

As Bryman (2012) notes, quantitative data interpretation is numerical while qualitative data interpretation is categorical. The quantitative data interpretation in the study was conducted by considering the mean (numerical average of the responses), the standard deviation (denoting how the response was distributed around the mean), and the frequency distribution (rate of response appearances). The three aspects of data interpretation are critical in this study because they describe the weight of the responses obtained, they ascertain the degree of consistency in the responses and they determine the degree of consensus among the responses given. Therefore, the quantitative data interpretation offered an opportunity for the researcher to come up with dependable results as the whole process was improved. The findings therein are factual and supported with numeric data which can thus help in making informed decisions regarding the present and make clear forecast regarding the future of hydroponics in the county of Meru.

3.7 Qualitative research method

The study was also carried out partly using the exploratory, qualitative research method. The study employed semi-structured interviews with select respondents who were more knowledgeable with the hydroponic systems such as the hydroponic systems suppliers. The sampling techniques used in qualitative research aims at achieving transferability of the findings rather than generalization through saturation where participants added to the sample continually until when there is sufficient insight about the phenomenon of study (Bryman, 2012). This is advantageous because it allows for the use of the largest possible number of sample participants thus increasing the study accuracy. Data collection under qualitative studies is succeeded by data saturation, coding, and analysis. Qualitative studies provide results that offer a rich description and strategic comparison across cases under study thus is less abstract compared to quantitative studies; it thus permits generalization to theory (Berg and Lune, 2012). This study sought to find out the rate of adoption of hydroponic farming system, farmers perceptions of the same, factors influencing adoption of the hydroponics farming methods and the role that extension officers could play in influencing the farmers to adopt the same to caution them against the vulnerability resulting from the effects of climate change in the study area.

The qualitative study approach was a suitable tool for the study based on its endeavour to focus on the interpretation of social phenomena from the target group's point of view (Creswell and Creswell, 2018). This aspect of the study design relates well to the objective of this study since the main aim was to get the farmers point of view on the adoption of hydroponics farming system.

3.8 Data collection (Qualitative method)

3.8.1 Semi-structured interviews

The study opted for structured interviews as it aimed at standardising the process of measurement. Bryman hints on the importance of having a standard process of measurement by noting that this is the reason why semi-structured and structured interviews are prominent in survey research. He also notes that this approach makes the set of questions to be standard to all the respondents. This greatly helps in keeping the error due to variation at a minimum which is extremely important especially when asking questions that are meant to be concept indicators (Bryman, 2012). This study sought to gather among others the farmers' perception on hydroponics farming and the factors that influence such farmers in the adoption of this system of farming. It was thus important to have an instrument that captures the data accurately without much variance in order to have factors that are common to most of the farmers in the target area while at the same time allowing the respondents some flexibility to delve deeper into the subject. A precoded interview guide was formulated that evaluated the farmers' choice based on parameters such as initial set up capital, the market, and availability of the relevant information.

Before the actual data collection, the researcher talked with the participants over the phone to familiarize and create a rapport which would go a long way in saving time. The sessions were preceded by formative virtual sessions that involved explaining the purpose and the significance of the study to the respondents. The interviews constituted of open and closed-ended questions. This was aimed at giving the respondents the flexibility to add other important opinions while at the same time sticking to the focus of the study. The bio-data and other relevant information were captured as the responses were recorded in an audio recorder to reduce the chances of losing information.

Data saturation was then ensured in the interview sessions by allowing the respondents to give their added opinions and any other information they thought was necessary for the study. The open question allowed the respondents to add all the information which the researcher was going to bypass.

The captured data was then coded using NVivo which allowed sorting them out to get general themes with regard to the research questions. This process allows for tagging of the most relevant information that was sought for by the researcher. Finally, data analysis was done through the following processes:

1. Transcription: the recorded information was transcribed (converted from audio to written form). This process is not very accurate because it omits non-verbal aspects of the interaction during the interviews.

2. Data Coding: this is the tagging of the most relevant data to curve out the most relevant themes. This was done through identification of the similar sentiments and words with regard to the same questions. It also identified the emphasis points in the responses. This procedure

is critical in that it helps the researcher to obtain answers and themes related to the research questions.

3. Generalization of themes and interpretation: the themes obtained from the coding exercise were used to compile general responses for the sample population. Finally, the generalizations obtained from the data were used to arrive at the responses to the general research questions.

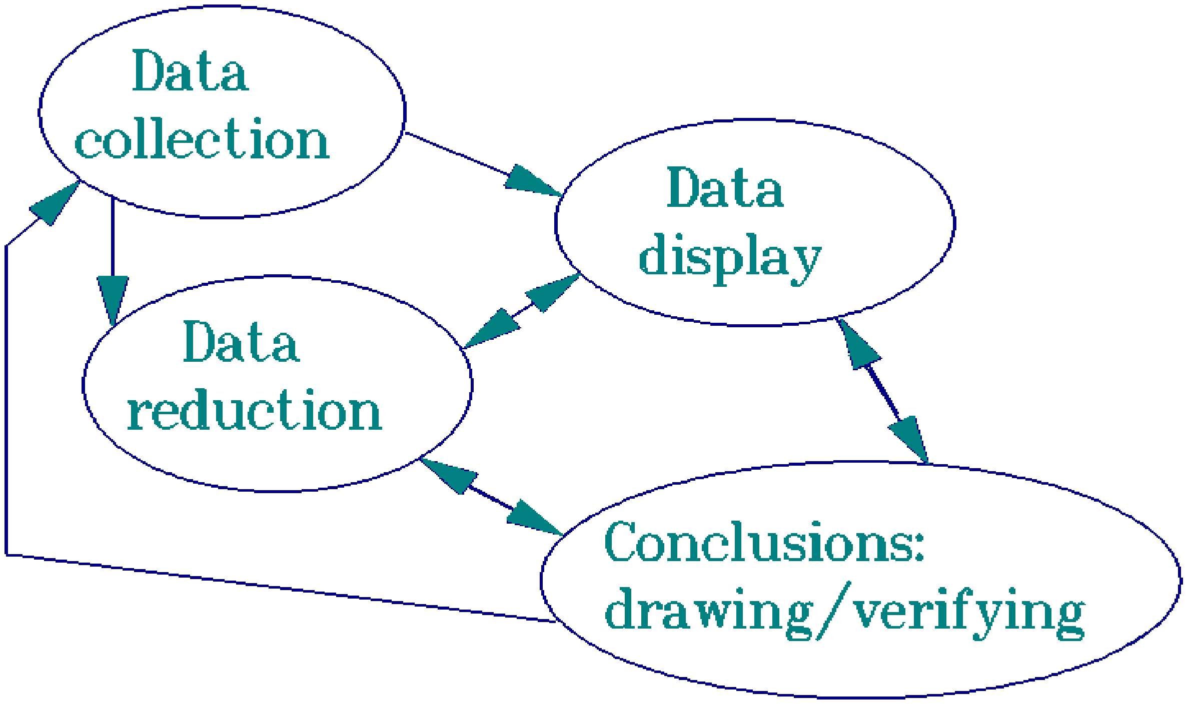


Figure 3. 1 Summary of the data analysis process

Qualitative research design was used together with quantitative methods because for instance, the cross-sectional design used in the qualitative aspect provides important data that that can be used in important decision making. This method helps to prove or disapprove assumptions and is not costly. For instance, an assumption that hydroponics is too costly was demystified through this approach. The method also allowed the researcher to use the findings to create new theories that can be used to form foundations of new studies. This design helped the researcher to create the foundations for possible future studies in the area with regard to the introduction of hydroponics in crop production.

3.8.2 Research design

The study banked on a case study to meet its aims and accomplish its objectives. The study sought to have a detailed examination, description and analysis of the factors affecting the adoption of hydroponics farming system in Meru. It thus opted to a case study as it entails a thick description, analysis and description of the specific case nature (Bryman, 2012). This quality of the case study makes it the most appropriate to be employed in the context of this study as it is imperative to deeply analyse the various aspects that includes the area demographics, access to capital, availability and cost of water and general market dynamics among other factors all of which inform and influence the adoption of hydroponic farming system. The case study's in-depth examination and analysis of the unit of study further endears it as an approach in this study as this is necessary in order to get a detailed analysis of the various factors influencing the adoption of hydroponics farming system among the small scale farmers in Meru County (Creswell, 2009, p.43)

The study used semi-structured interviews from survey questionnaires for data collection to afford the respondents an unlimited freedom to express themselves (Bryman, 2012). The views and opinions of the participants were important to the study hence the use of Open ended questions to facilitate this objective (Creswell, 2009). The use of Open ended questions also allowed the respondents to provide additional supplementary information that could be useful to the study.

3.8.3 Study area

3.8.4 Kenya

Kenya is an East African country. According to Brand Kenya (2018), the country has a coastline on the Indian Ocean. The Kenyan landscape varies from the mountain highlands, the Savannah, Lakelands to the famous rift valley. The capital city of Kenya is Nairobi which also doubles as the seat of the Kenyan government.

Kenya covers 580,367 square kilometres, ranking the country as the 49th largest country in the world. Out of this area, 569,140 square kilometres is landmass while the remaining 11,227 square kilometres is covered by water. A total of five countries share a boarder with Kenya. They include; Ethiopia, Sudan, Tanzania, Somalia and Uganda (Brand Kenya, 2018).

Kenya has got two rainy seasons with the long rain season lasting between April and June, whereas the short rain season comes in November and December. This is normally followed by a dry rainless season which lasts between mid-December to the end of March (Brand Kenya, 2018).

The Kenya population census of 2019 shows that Kenya has a total population of 47,564,296 out of which 23,548,056 were male, 24,014,716 female and 1,524 inter-sex. Kenya has got 47 counties with Meru county having a population of 1,545,714 people (KNBS, 2018).

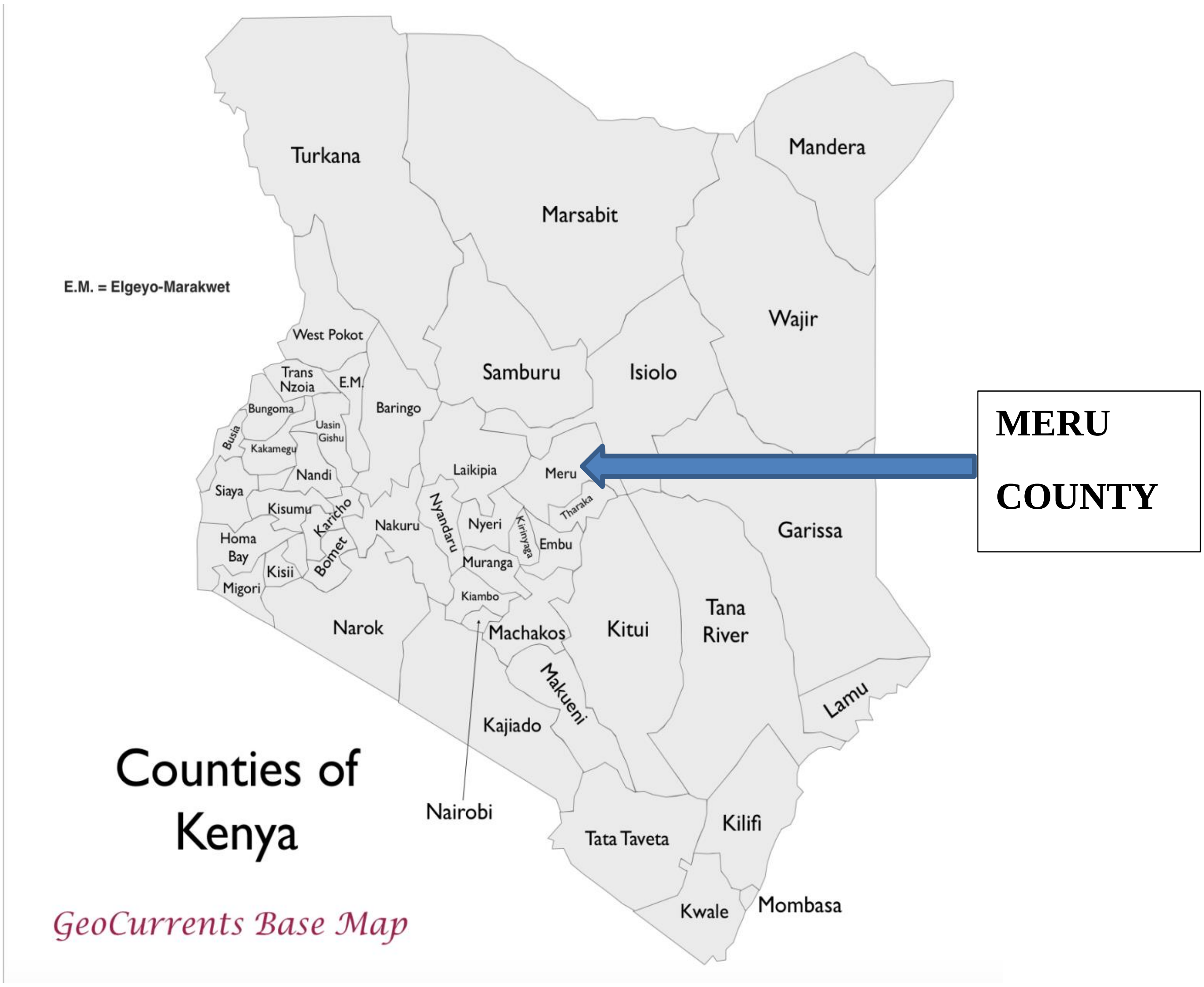


Figure 3. 2 The map of Kenya indicating the study area; Meru County.

Source (Geocurrents, 2016)

3.8.5 Meru county

Meru county is located east of Mt.Kenya with a total land mass of 6,936 square kilometres. It borders Tharaka-Nithi, Isiolo, Nyeri and Laikipia counties. Agriculture is a key economic activity in the county (Meru county government, 2020). Meru County has a predominantly young population with 40% of the population being below 14 years and 35% of the total population aged between 15 and 35 years. A total of 21 % of Meru county residents have no formal education. 18% of the residents who have a primary education and 27% of those with secondary education work for pay. 62% of the Meru population have only attained a primary level of education (KNBS, 2018).

Meru County can be sub-divided into four main agro-ecological zones depending on the rainfall patterns (MoALF, 2016);

- The upper highlands (altitude 2230-2900m above sea level) which take the most part of the county from Imenti South, Imenti Central, Tigania East and Imenti North, Buuri, Igembe central and Tigania East. This region experiences rainfall of about 700-1000mm per annum and a temperature range of between 14.9^{o}C to 10.5^{o}C

- The lower Highlands of altitude 1830-2210 metres above the sea level have an average rainfall of between 800 and 2600mm per annum and temperature range between 17.4^{o}C and 14.9^{o}C

- The upper midlands found between 1280 and 1800 metres above sea level experience rainfall of between 500 and 2,400 mm per year. It experiences a temperature range between 20.6^{o}C and 17.6^{o}C.

- The lower midlands which are found 750-1300 metres above the sea level experience rainfall range of between 560-1600 mm per annum and temperature range between 24^{o}C and 20.9^{o}C.

Similar to most of the other Kenyan counties, agriculture is Meru County's primary economic activity divided into animal keeping and crop production. Food crops cover up to 161,907ha while cash crop covers 15,773ha of the land area. The two makes up 26.3% of the land mass. According to GOK (2014), the mean total value of household income in the area is 258,028 Kenyan shillings (equivalent to approximately 2,500 USD). The on-farm income is KES 97,740 per annum with the off-farm income averaging to KES 86,576 per year (KNBS, 2019). It is worth mentioning that the workers in Meru County are mainly employed in the agricultural sector, implying that labour force is more than available in the agricultural sector in the area.

The agricultural labour (both family and hired) is predominantly provided by the youth. There is unequal distribution of land in the area as large scale farmers hold most of the lands with the households mainly left to take the remaining parcels of land which are predominantly very small in size. According to GOK (2013), the actual land holding size is about 1.8ha as the large scale holding is about 18.25ha. Wheat production is the main large scale crop production activity. The majority of farmers use approved farm inputs such as improved seed varieties, fertilizers, pesticides and also organic manure.

Meru County has a large unutilized irrigation potential due to presence of 11 permanent rivers but only 14% of households using irrigation water (GOK, 2014). The area under irrigation in the county is only about 15,000 ha while the total potential is about 80,000 ha. Protected springs, protected wells, boreholes, piped and rain water collection forms improved water sources in Meru County. Other water sources include ponds, dams, lake, streams and rivers (KNBS, 2018).

The study's choice of Meru County as a case study was informed by the increased interest in hydroponics farming in the area. Recently, Hydroponics Africa, one of the pioneers of hydroponics farming system in East Africa, benefited from a grant that saw them expand their operations from Kikuyu to Meru regions ('Hydroponics Africa Limited | KCIC', 2018).

3.9 Theoretical framework

3.9.1 Systems analysis

The study was guided by the systems analysis theory. A systems analysis can be described as the process of studying the systems boundaries, investigating it's users, inquiring on its processes, and establishing its inputs and outputs with the intention of proposing a more economically feasible and efficient way to solve the challenges in question (Silver and Silver, 1989). Systems theory is interdisciplinary because it explains almost every system in nature, society and in diverse scientific areas. It can be used to investigate all phenomena from a holistic approach; it has enhanced the shifting from part to the whole phenomenon. This theory takes into consideration a wide field of research but mainly deals with the complexity of interacting elements. Systems theory mainly focuses on interactions by analysing the factors favouring such relationships. It is worth noting that a single autonomous factor or variable behaves differently in its independent state as compared to its behaviour in an interactive environment.

The systems theory is based on the belief that people do not operate in isolation but constantly interact with both the physicals and the social environment (Cristina et al., 2010). Systems theory explores the interconnections and the interactions that make a society complete. The systems usually constitute the individuals, couples, communities, the society, organizations and the world as a whole. The theory holds that each system consists of several elements that are interrelated that make the whole system functional

The systems theories are critical in social sciences because they provide a theoretical basis used for assessing subjects holistically by examining all the systems in the ecosystem. In this study, the research questions were better if analyzed by using the systems theory. First, in order to investigate if the different actors involved have a role to play in supporting or encouraging the farmers' adoption of the hydroponics system, the research applied the holistic study of the systems that affect agriculture in the county, ranging from land, rainfall, capital, etc. Secondly, in order to investigate if the production costs and the access to capital to cater for such costs attract or constrain the farmers from adopting the hydroponics system, the researcher considered the systems that affect individual income in the county, the nature and source of labour in the county as well as other factors that directly or indirectly affect financial ability of the farmers under study. Thirdly, in order to underscore the other factors that could have an effect on the farmers choice of crop type to produce in Meru County, the researcher explored the economic strength of the farmers, the resources, the crop yields and the access to market; these are part of the systems that together affect the ability or inability of the farmers to put up hydroponics farms in the area. Finally, to assess the challenges, opportunities and constraints that farmers meet in their adoption or development of hydroponics growing systems in the area, the researcher studies the political and the policy measures in the county that affect agriculture.

Studies have suggested specific steps that could be followed in a systems analysis approach. (Parkin, 1980); (Daniels and Landers, 1981); (Michie, 1982) suggests the following steps for a successful and comprehensive systems analysis;

- ❖ Conduct the feasibility of the system-Here the researcher should inquire on the time, labour and financial cost needed to make the system successful.
- ❖ Find out the various actors interacting with the system and establish their needs with an aim of understanding and suggesting feasible solutions to their requirements.
- ❖ Search the existing data for the available procedures to find out the existing limitations and suggest techniques and procedures that can be employed for future development.

One of the most important attribute of system analysis is that it consistently and systematically analyses the variables that 'constitute its whole' (Pahl-Wostl, 2007). This study sought to analyse the various variables that interact with hydroponics farming system and integrate them to generate a general overview of the system as a whole. It also investigated the roles, needs and input of various actors interacting with the system to provide a comprehensive and collective feedback on the possible solutions to the various actors needs and input in order to make the whole system successful or suggest future interventions for such success.

3.9.2 Ethical considerations

Informed consent was sought from the respondents to allow for audio recording of the interviews for later transcription in order to ensure that the relevant data was captured as accurately as possible. The researcher intended to inform the respondents of their right to privacy and enumerate to them the steps that were taken to ensure their privacy was guaranteed. Such steps included the use of coded names to ensure that the respondents' identity was not easily inferred.

The researcher also sought and was granted the necessary approvals to conduct the study both from the Norwegian and Kenyan authorities. As part of the evaluation procedures for such permits, the researcher elaborated a set of measures that were necessary to ensure an ethical adherence in the conduct of the study. These guidelines were strictly followed and adhered to in the process of conducting the study.

After data analysis, the findings were sent out to the respondents to afford them an opportunity to confirm if the findings reflect the true representation of the situation under analysis and to seek for their opinion on the final representation of the findings before publishing.

3.9.3 Study validity and reliability

The essence of mixed methods study is to make sense of and recognize patterns in the area of study. The quality of the data obtained in the study is thus of critical importance and it can be assessed using six criteria that include clarification and justification, interpretative rigour, data representativeness, reflexive and evaluative rigour and its ability to be transferred and generalized. The validity of study findings, according to Creswell (2015) refers to the appropriateness of the tools used in the study. For instance, is the methodology used appropriate in answering the research questions, and are the sampling and data analysis procedures appropriate? Validity in this study was ensured through ascertaining that sampling was randomly done and that the best sample population was considered. Reliability on the other hand, may refer to the ability to replicate the findings of a study by employing a similar process (Grossoehme, 2014). Validity and reliability were measured by way of triangulation and trustworthiness. Bryman vouches for triangulation as a way of corroborating findings (Bryman, 2012, P.635). In this case, use of document analysis was aimed at verifying and authenticating the interview findings. Bryman (2012) sets the four criteria for measuring trustworthiness namely; dependability, transferability, conformability and credibility. This study endeavoured to consider these trustworthiness parameters in ensuring that the study findings emulate a true reflection and representation of the study objectives. Reliability was affirmed through data verification for their accuracy by analysing both the context and content when comparing the responses from the respondents.

3.9. 4 Sampling

Time and resources could in most cases limit the researchers' ability to conduct a whole population census and thus it is common practice to resort into analysing a section of the target population as a representative of the whole population. This therefore calls for a need to have a sample that is representative enough of the population under analysis and one that greatly reduces the sampling error. This calls for a sample that can be generalized to the entire population while eliminating a sampling bias. Probability sampling has been vouched as one method of sampling that is both representative and has the ability to 'keep the sampling error to a minimum'(Bryman, 2012). The selection and the recruitment of the participants usually aim at achieving transferability in qualitative research and generalization in quantitative research. Therefore, the sampling technique used in this study intended to increase both transferability and generalisation. Sample saturation is an important aspect of sampling and this was done by taking a large number of participants through probability sampling. Probability sampling is random and in most instances representative of the whole population.

3.9.5 Simple random sampling

Both time and resources being a key consideration for this study, the study sampled a section of farmers in Meru County who were well representative of the entire population and ones who could be generalized to the entire population with minimal bias. This makes a probability sampling method best suited for that purpose. While making a case for probability sampling method in comparison to non-probability sampling method, Bryman notes that human judgement is likely to inspire biasness in the sample selection in the case of non-probability sampling an attribute that is least likely to occur in probability sampling (Bryman, 2012).

Among the various probability sampling methods, Simple random sampling method is best suited for this study as it takes less time and resources in its approach. The study took the form of simple random sampling without replacement to avoid situations of a participant being tallied more than once. Subjects in the population were sampled at random by using a random number table after identifying a large number of possible participants. Some 250 participants were randomly sampled from 1000 possible participants. Simple sampling without replacement offers a sample mean that is an unbiased estimation of the population mean. Also, the average variance of all the possible samples is equal to the modified population variance. This is because in simple random sampling the researcher determines the resources available for the study and decides the number of respondents that can comfortably be reached with the resources at hand. The researcher then generates random numbers and goes for those that are within his sampling frame. Simple random sampling is more simple and convenient to use in this study as compared to other probability sampling such as the stratified sampling. In stratified sampling the researcher has to divide the entire population into distinct groups (strata) (Bryman, 2012). In this study, it was difficult to obtain prior distinct population demographics that can be generalized to the entire population and thus the choice for simple random sampling.

Generally, simple random sampling was used because of the respondents are chosen at random and each individual chosen is at the same probability of being selected. Therefore, a balanced subset that holds the highest potential of full representation of the whole set is selected thus minimizing the possibilities of bias. Additionally, simple random sampling, especially without replacement is less complicated that the other sampling methods (such as stratified random sampling). However, simple random sampling bears some drawbacks that are worth mentioning. First, the process faces difficulty in obtaining the full list of the possible sample population. This did not affect the sampling in our study because the list of all hydroponic farmers in the county were easily accessed because of the relatively small number that so far employed the agricultural technology in the area. In a study with the possibility of larger populations, simple random sampling method becomes time consuming and costly especially due to the need of retrieving the information regarding the whole population. Finally, simple random sampling in some occasions may encounter sample bias especially when a sample set of the larger population is a well representation of the general population; this also occurs where the target population is very large. The study opted for the use of simple random sampling method because all the discussed disadvantages emanate from the complexity of large target populations. Our study however targeted a small set of farmers who has so far employed the hydroponics technology in crop production.

3.9.6 Sample size

The study aimed to sample 250 farmers. In coming up with this sample size, considerations of the representativeness of the sample and the idea of generalisation of the sample to the entire population was put into mind. Bryman asserts that a sample represents the population more effective with it increases in size (Bryman, 2012). He however warns that increasing the sample size does not always guarantee precision but it increases the likelihood of such precision. He advises that the main focus should be in decreasing the sampling error as an increase in the sample size most often leads to a decrease of the sampling error (Bryman, 2012a). A further consideration on the time and resources available for the study further informed the settling of the sample size of 250 farmers. Bryman agrees to such consideration by arguing that apart from the considerations based on precision and representativeness of the sample, other factors such as time and cost also inform the size of the sample selected (Bryman, 2012).

4 DATA ANALYSIS

4.1 Introduction

Bryman refers to data analysis as the process of interpreting, analysing and managing the data (Bryman, 2012). In collecting the data, interviews were conducted based on a prepared questionnaire. Consent was obtained from the respondents to record the interview on an audio mobile recorder to ensure accuracy in the capture of the information obtained. On the need to record, Bryman teach that such recording serves in reminding the researcher of information he might otherwise have forgotten. He further argues that recording provides the researcher an opportunity to review what the respondents said in order to get a true and clear representation of the information for analysis. In a further argument for recoding, Bryman teach that it is not only enough to get a clear indication of what the respondent said, but also how he said it for an effective analysis of the data obtained (Bryman, 2012).

The table below represented the data analysis methods used in the study.

Table 4. 1**Data analysis**

Research Questions	Data Type	Data Analysis
What is your level of Education?	Quantitative and Qualitative	Descriptive analysis with frequency tables
What is your age?	Quantitative and Qualitative	Frequency analysis with tables
What is the cost of operating the hydroponic system based on the following parameters?	Quantitative and Qualitative	Frequency analysis with tables Thematic analysis
What type of crops do you grow and what are their yield levels per season/harvesting intervals? Any preferred crop	Quantitative and Qualitative	Frequency Distribution Thematic analysis

type and why?		
What would you term as the major challenges and constraints facing hydroponics farming in Meru?	Quantitative and Qualitative	Frequency Distribution Thematic analysis

For the research questions 3, 4, and 5, the data obtained was thematically coded and analysed qualitatively. The coding was based on the themes presented in the study objectives. Other important themes were also analysed to establish their contribution to the overall system characteristics.

Research question number three, which deals the various costs involved, was analysed quantitatively. The researcher adopted the use of SPSS, excel and a statistical software; the R, to run a multivariate regression analysis on the data collected. This was attempted to establish whether or not there was any correlation between the multiple variables under study. Tables of the various measures of central tendencies were derived from the data to present the findings with a brief description of their implications to the study. Pie charts and tables were applied appropriately to further elaborate on the findings.

4.2 Limitation of the study

The study faces some limitations. For example, the data was not readily available given the fact that some hydroponic farmers felt that their hydroponics farming strategies are confidential and exposure of the same may help their competitors. However, the researcher promised all the respondents that the data gathered in the study was meant for academic purposes only. This later convinced the respondents to divulge key information on the factors affecting their hydroponics farming and how they plan to improve.

Another key limitation was the busy schedule of some of respondents who were mainly farmers. However, to help achieve the research objectives, the researcher organized online and phone interview to confirm the schedules of the respondents and this made it possible to achieve a high response rate during the study. Moreover, time and resource constraints were also a big challenge in this research.

5 RESULTS/FINDINGS/DISCUSSIONS

5.1 Introduction

This study collected numeric and qualitative data using the survey method. A presentation of the analysis and the resulting findings is presented in this chapter. The cardinal objective of the research was to find the factors that are associated with the adoption of hydroponic farming system in Meru County, Kenya. Various objectives were pursued in the study. First, the study explored the stakeholders involved in hydroponics farming and their influence in hydroponics adoption. Second, the study recognised the influence of access to capital as well as the cost of production, as important determinants in the adoption of hydroponics farming. In particular, Meru County faces major challenges with respect to access to capital because many farmers lack collateral to access funds from financial institution. In the backdrop of these factors, the study aimed to establish the impact of capital and cost of production on the adoption of hydroponics farming in Meru, Kenya. The study further sought to explore whether access to water is associated with the adoption of hydroponic farming. Another objective of this research was to find the challenges, opportunities, and constrains in the adoption of hydroponic farming. Lastly, the study was aimed at establishing if crop yields, access to markets, and economic returns influence the decision of farming concerning the adoption of hydroponic farming.

5.2 Background, adoption rate and development of hydroponics in Meru.

Hydroponics farming has continued to gain popularity in Meru County in the recent past with over 1000 farmers having adopted the technology. This represents an adoption rate of only 5% (Kibiti, 2017). However, there has been an increasing popularity of hydroponic farming in Meru since 2016. The increasing popularity could be attributed to the entry of new actors in the Meru region. One such organization working with farmers in the area is Hydroponics Africa limited, a company specializing in the construction of hydroponics systems. This company offers training to the farmers on new crop varieties, different hydroponics systems suitable for their needs and the general maintenance of the system. They also help link the farmers to the market and advice on alternative credit facilities available both from government corporations and the private micro-finance institutions (‘Hydroponics Africa Limited | KCIC’, 2018).

In 2016, Hydroponics Africa expanded their services to Meru County as a result of the proof of concept grant they received through the Kenya climate innovation center. KCIC is a World

Bank initiative meant to encourage new clean technologies that cushion against the effects of climate change. They encourage new climate smart innovations in water, energy and agri-business sectors (‘Hydroponics Africa Limited | KCIC’, 2018).

Many farmers in the area who participated in this study hinted on having received training from Hydroponics Africa limited either from a training workshop held in the area or from visiting the model farms operated by the firm in Kikuyu Kenya. Other private companies specialising in hydroponics system manufacturing have also started their operations in the region. Some farmers hinted on having bought their hydroponic systems from Grandeur hydroponics limited.

The study established that some farmers had access to credit. The government through the Agricultural finance corporation advance loans to farmers in the region to enhance their agribusiness. Several microfinance institutions also offer loans to the farmers. Farmers cited having received credit from Acumen microfinance through the ‘juhudi kilimo’ loans initiative by the microfinance aimed at assisting farmers explore costly but profitable ventures. Other micro-finance institutions working with farmers in the area include ECL of Kenya and the local farmers initiated savings and micro-finance institutions. However, most of the respondents decried a lack of collateral for the loan since the finance institutions asked for the same before advancing loans. Some of the young farmers were doing their trade on inherited ancestral land whose transfer was yet to be effected in their names and thus they couldn’t use the land as collateral for the loan. Others had applied for the land transfer but they noted that the process is long and costly.

The study found out that the initial cost of installation of the hydroponic system depends on the size. The most common sizes installed in the area are 8meters by 15 meters and 8meters by 30 meters. Their costs range from Kes.250, 000 (USD 2,500) to Kes.500, 000 (USD 5,000) respectively. Those operating the 8meters by 30 meters greenhouse hydroponic system reported a yield of up to 5tonnes of tomato production per year. The 8 meters by 30 meters had the double production yield at 10 tonnes per year.

The respondents noted that their profit margins vary depending on the management practices as if not well managed some crops such as tomatoes are prone to attack from pests and diseases. The study found out that the most common type of pests and diseases in the area include; trips, leaf miner, and powdery mildew. An interview with one of the experts in the area revealed that they encourage farmers to use environment friendly products to control the pests and diseases. He termed pyrethrum and garlic extracts as one such effective organic product in controlling the pests.

Most of the respondents reported a profit from the hydroponics farming. The profit margins ranged from Kes200, 000 (USD 2,000) to Kes.600, 000 (USD 6,000) per year. This depends on the type of crop grown and the management practices adopted. Those growing high value crops such as lettuce, Broccoli and Strawberries reported having higher returns compared to the ones growing Kale and tomatoes. However, some of the farmers argued that Kale and tomatoes despite having lower profit margins had a readily available local market and this influenced their choice of the two.

Other crops commonly grown in the area under hydroponics include cabbages and fodder for feeding the livestock. The livestock fodder was also termed as lucrative as it was high on demand in the area especially during the dry seasons.

The automated nutrient film technique is the most commonly adopted hydroponic technique in the area. The system is built on either metallic or wooden support structures with hollow PVC pipes running across the structure. Some small pipes feed water enriched with the mineral solutions to the system. The PVC pipes have holes drilled on their upper side on a predetermined sequence. The pipes are then filled with the support media (mainly volcanic rocks and pumice). The water and mineral solution is stored in an elevated storage tank. Reservoirs are designed at the lower part of the system where the water and mineral solution is collected and pumped back to the storage tank using a small electric pump. Most of the electric pumps in the area are solar powered. The figure below shows a photo of the hydroponic system adopted in the area.

Author, 2020

Figure 5. 1 A photo of the hydroponics system adopted in Meru County.

The hydroponic fodder system consists of aluminium trays that hold the support media. These trays are arranged in the metallic or wooden structure in a slanting vertical format to enable water and mineral solutions to flow from the upper to the lowest layer where it is collected in a reservoir. The solution is then pumped back into the system by a small electric pump mostly solar powered. The figure below shows the hydroponic fodder system.

Author, 2020

Figure 5. 2 A photo of the hydroponic fodder system adopted in Meru County

5.3 Questionnaire response rate

A questionnaire was the instrument of choice in gathering the data on which this study relied. The questionnaire was administered to a total of 250 people. Out of this, 230 people filled and returned the questionnaires, hence accounting for 92% response rate. This response rate was adequate for the analysis in this study considering that it fulfilled the requirement of at least 50% response rate recommended by Babbie (2002).

5.4 Demographic data

5.4.1 Gender of participants

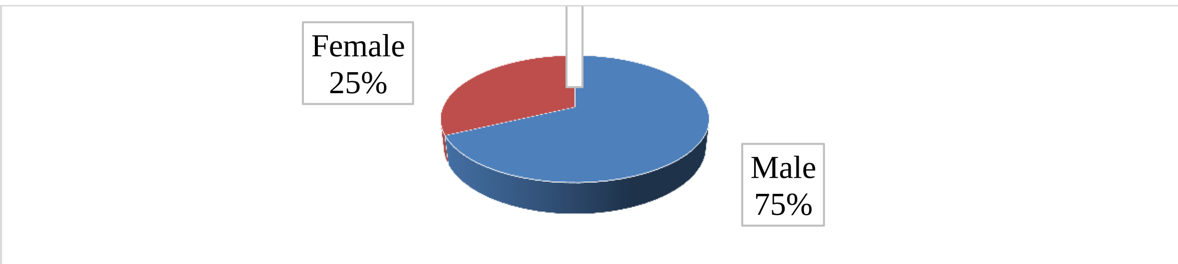
One of the items in the questionnaire administered to the respondents required them to indicate their gender. Demographic data is a significant factor in the study since it plays a significant role in influences some of the variables involved in this study. Gender distribution among the respondents participating in this study is captured in the following table.

***Table 5. 1*: Distribution of farmers by gender in Meru, Kenya**

Gender	Frequency	Percentage
Male	171	75
Female	59	25
Total	230	100

According to Table 1 shown above, 75% of the respondents were male while 25% were females. This implies that farming in Meru County is dominated by males. This is further elaborated in the figure below

Figure 5. 3 Distribution of Gender



Sourced from the research data, 2020.

5.4.2 Age of the respondents

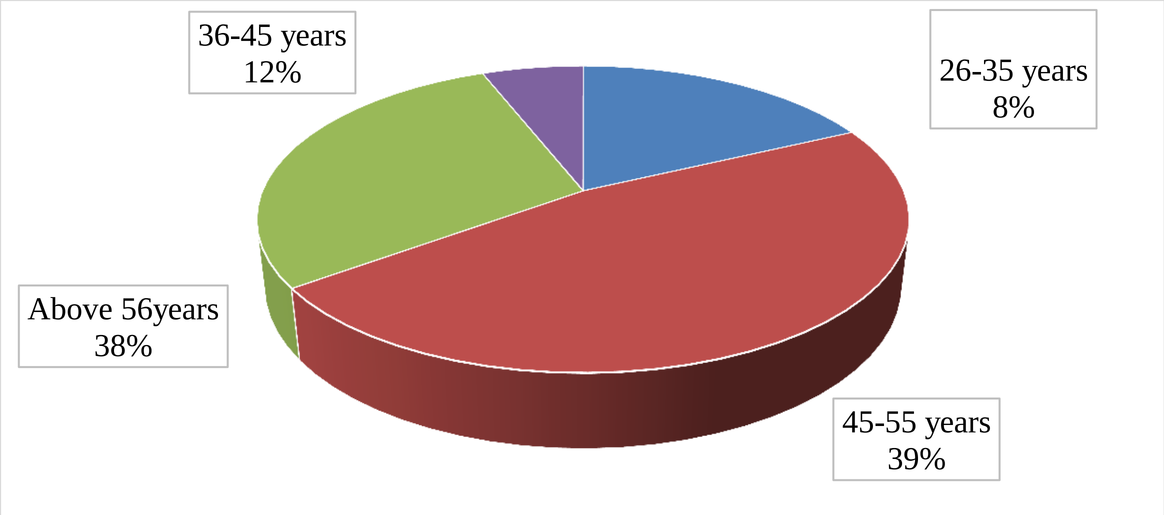
The questionnaire used in the study also aimed at determining how the respondents' age was distributed. Age is an important factor in this study since it influences various variables. For example, it can be argued that younger people are more likely than their older counterparts to try new farming methods. Therefore, it is important to find out whether age could explain possible variations in the readiness to adopt hydroponics farming among the various age groups.

Table 5. 2**: Distribution of farmers by age in Meru County**

Age	Frequency	Percentage
18-25	7	3
26-35	19	8
36-45	27	12
46-55	89	39
Above 56	88	38
Total	230	100

Table 2 above shows that most farmers in Meru County are aged above 45 years. This point to possible influence of various generational factors on the farming decisions among this group as indicated in the figure below.

Figure 5. 4: Respondents Age bracket



Source: Research data, 2020.

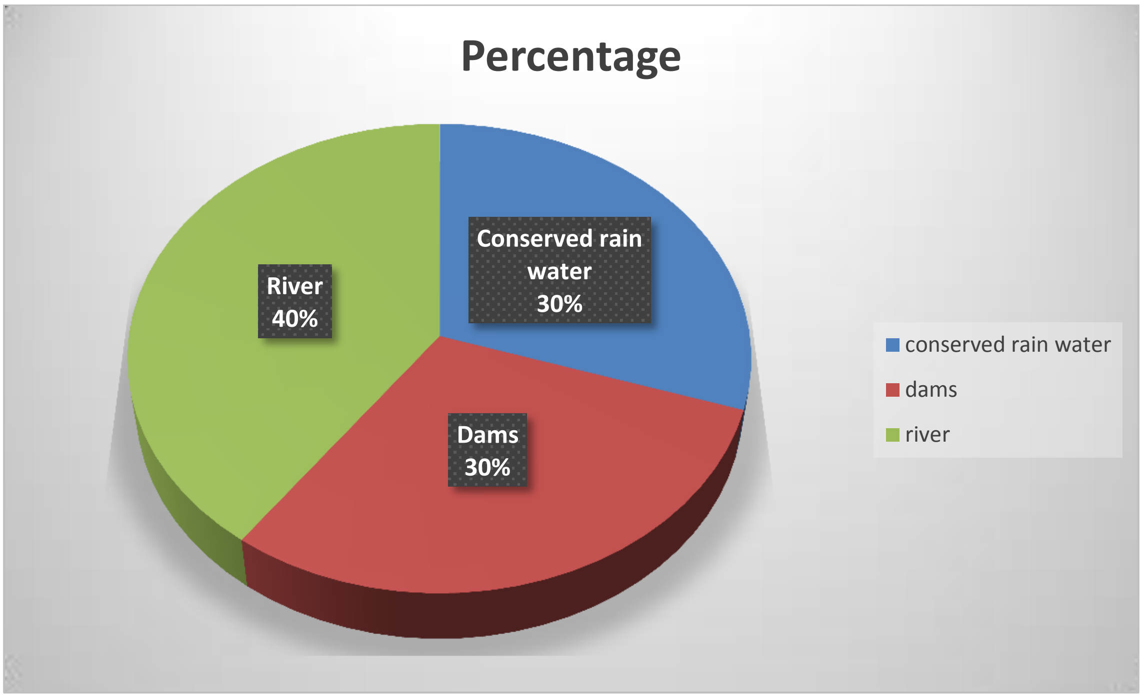
Based on the figure above, it is evident that the majority of the study respondents were between the age of 45-55 years and this is a clear indication that majority of hydroponic farmers in Kenya are above 45 years. However, it should be noted that only 8% of the youths between the ages of 26-35 years have invested in hydroponic farming in Kenya. This presents a risk to the continuity of hydroponics farming in Meru County.

5.5 Sources of water for hydroponics

The source of water for hydroponics farming was among the factors that the study sought to establish. From the analysis of the study results, it was evident that the majority of farmers in the country depended on surface water as the main source of water for their hydroponic farming activities. Some farmers also depend on dams and conserve water sources such as the use of tanks.

A close analysis of the study findings also indicated that some of the farmers have underground wells as a source of water for their hydroponic farming. This was then piped to irrigate their crops. From the farmer's perspective, the use of surface water was cheaper and easy to harvest. Lack of water was a big challenge to many of the farmers and water scarcity led to low production in some seasons. They used the stored water during dry season to water their crops. Thus, it is evident that many farmers preferred surface water as the major source for their hydroponic farming in the study area as shown in the figure below.

Figure 5. 5 Sources of water for hydroponics



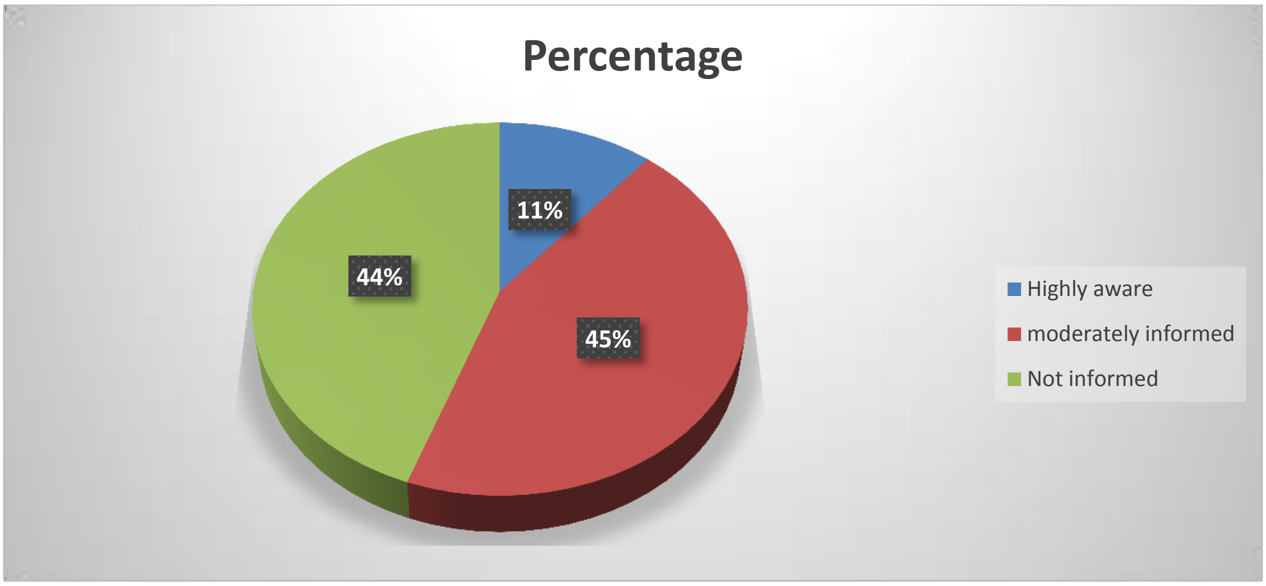
5.6 Farmers Awareness and Training Levels

The researcher sought to determine the levels of farmer's awareness and training levels in relation to hydroponics farming in Kenya. The farmers hydroponic farming awareness levels was measured by a number of factors and conditions. Some of the conditions used include whether they get training from extension officers in the community or not. The study questions also determined the farmer's levels of network based on hydroponics in the community.

Summary of the farmers awareness levels are illustrated in the figure below and it is evident from the figure that majority of farmers in Kenya are not properly informed about hydroponic farming. Only 11% of Kenyans are aware of hydroponic farming and this is partly because they have received trainings associated with hydroponic farming in the country. The training farmers gained from the country mainly come from NGOs and private sector groups. Notably, some farmers within urban centres in the country were moderately aware about hydroponic farming as shown in the figure below.

Figure 5. 6 Farmers awareness

Source: Research data, 2020



Some of the farmers also indicated that they have gained training from government agencies. However, there were also farmers who indicated that they have gained training through social media and through attending of workshops and seminars in the community. Social media also acted as the leading source of information creating awareness among the farmers practising hydroponics farming in the area.

5.7 Cost of operating hydroponics in the area.

The study sought to determine the cost of operating hydroponics in Kenya. Based on the data findings, it was clear that most of the farmers reported high cost of operations as the main challenge. The farmers reported that they incur a high capital input of up to Kes.1.5 Million in setting up their hydroponic structures. However, the initial set up costs varied depending on the size of the hydroponic structure. The most common ones in the area were 8 meters by 15 meters and the 8 meters by 30 meters.

It is however worthy noting that the hydroponic system manufacturers allow the customers some flexibility to order for the sizes that fit their needs. The cost would thus decrease proportionately as the structure size decreases. According to the hydroponics company field officers, the company encourages the two standard sizes of 8 meters by 15 meters and 8 meters by 30 meters as they hold sufficient crop capacity that guarantees the farmer some good returns based on the economies of scale.

The table below shows the average cost of setting up a hydroponic structure in the region.

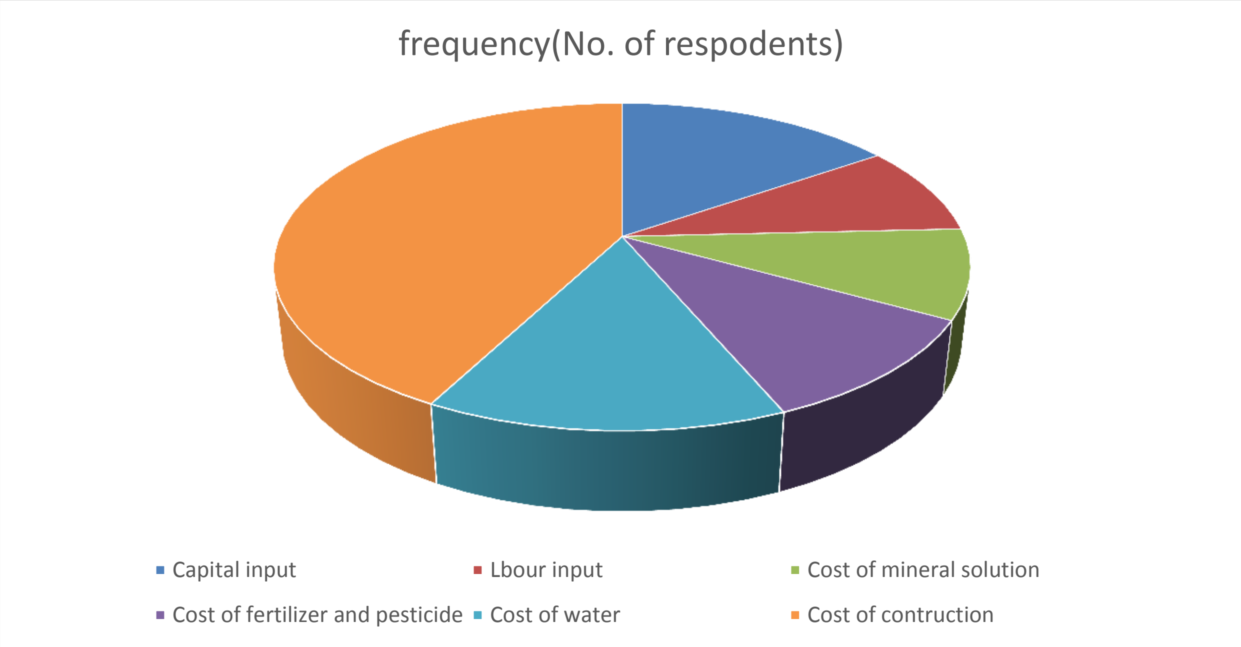
SIZE	8 METERS BY 30 METERS (KES.)	8 METERS BY 15 METERS (KES.)
Structure cost	500,000	300,000
Labour(Construction)	30,000	18,000
Cost of mineral solution	150,000	80,000
Fertilizers and pesticides	120,000	55,000
Water	10,000	4,000
System Automation	450,000	250,000
Crops	240,000	105,000
Grand total	1,500,000	812,000

Table 5. 3 Average initial cost of setting up a hydroponic system.

Research data, 2020

The results from the table above are in line with the arguments of Kibiti (2017) that access to capital is one of the major determinants of uptake of hydroponics farming. In the long term, however, it is notable that there is a decline in the cost of maintenance mainly in the form of labour inputs, standing at an average of Kes.10, 000 per month. The implication is that contrary to the arguments of Tripp (2014), the cost of maintenance is not one of the primary inhibiting factors to the uptake of hydroponics farming. To enhance the uptake of hydroponics farming in Kenya's Meru County, the government should provide financing mainly to cater for the initial investment cost.

Figure 5. 7 Cost of operating hydroponics in the study area



From the data gathered, the farmers also indicated that cost of fertilizer and pesticides was a big challenge in their operations. This is because the majority of the farmers used around Kes. 55,000 to Kes.120, 000 depending on the size of their farming system to purchase fertilizers and pesticides for their operations. However, it was evident that cost of mineral solutions and water was also a big challenge towards the farmers operations. For example, many farmers indicated that the cost of water and mineral solutions was about Kes.55, 000 and Kes.80, 000. They noted that the high cost of pesticides affected their operations in cases of high pest infestations. Generally, it should be noted that the cost of construction of the hydroponic setup was between Kes. 300,000 to about Kes.500, 000 depending on the size of the structure constructed.

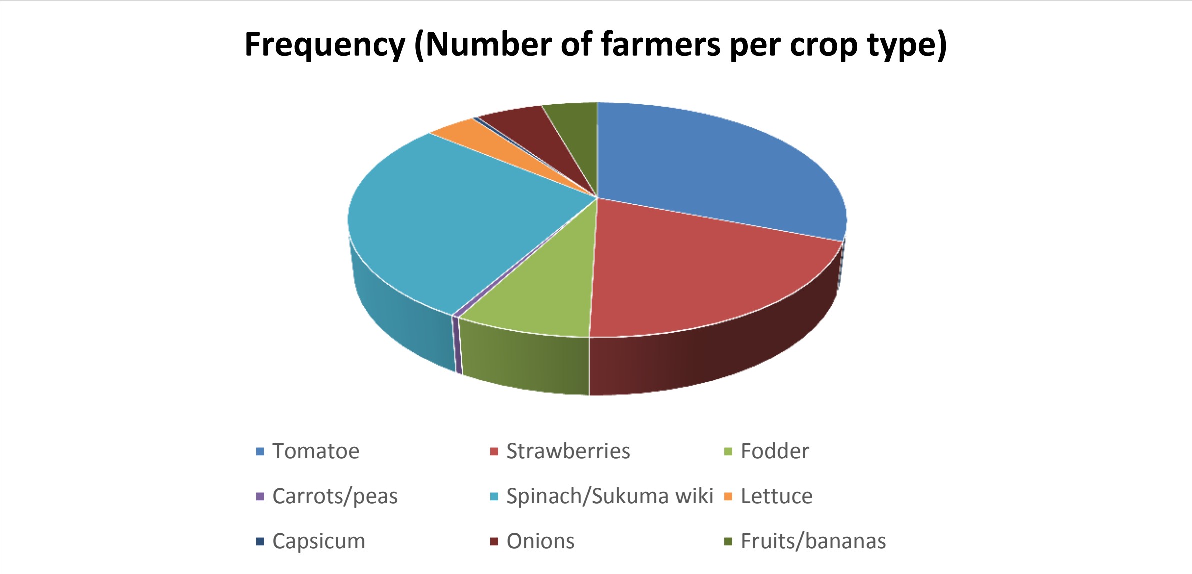
The observations above are in line with the theoretical framework fronted by Tripp (2014) where he argued that the high cost of inducing nutrients in water presents one of the major challenges to the practice of hydroponics farming. This is further illustrated in the following table.

5.8 The type of crops grown by hydroponics farmers

The study sought to determine which crop varieties were grown by different hydroponic farmers in the study area. From the analysis of the findings, it was evident that the farmers have grown different crops such as fodder, sukuma wiki (Kale), peppers, spinach and onions as well as potatoes and cabbages. The farmers also cultivated the fruit juice, bananas and tomatoes. Other major crops grown by the farmers included carrots, peas and maize.

Kibiti (2017) contends that hydroponics farming is most suitable for crops with short maturity. The rationale is that the short turnaround helps farmers to recoup their initial investment. Indeed, from the majority of the farmers in this particular study, it was evident farmers cultivated crops with a short maturity period. These crops gave the farmers the opportunity to generate income within a short time. The figure below depicts some of the crops grown by the farmers. The selection of these crops with short maturity confirms the claim that the type of crops is one the primary determinant of the uptake of hydroponics farming as noted by Kibiti (2017). From the figure, it is evident that fodder, tomato, carrots and fruits/bananas and spinach were the main crops grown by the farmers in Kenya.

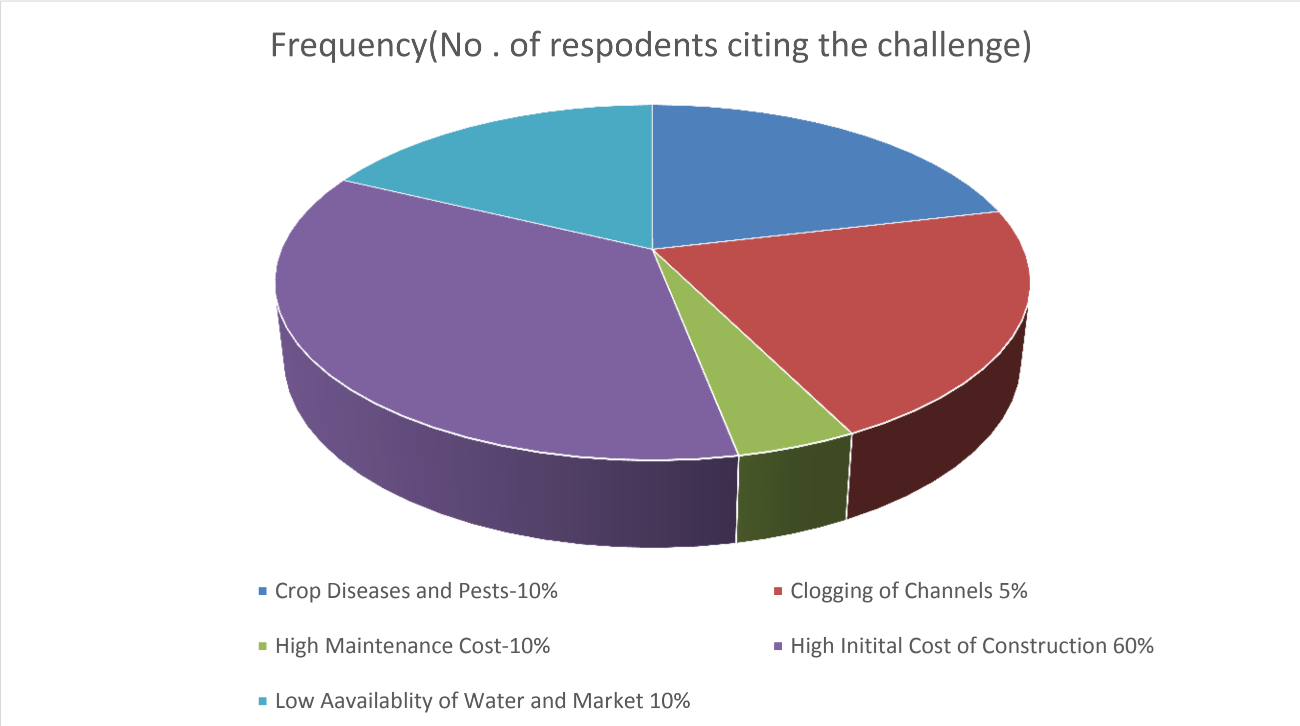
Figure 5. 8Type of crops



5.9 Challenges facing hydroponics farmers in Kenya

One of the objectives of this study was to find some of the challenges facing hydroponic farmers in Kenya. From the findings given by the respondents, it was evident that there are various challenges facing the hydroponics farmers in Kenya. Some of the challenges noted by the majority of the respondents included crop diseases and pests, high initial cost of constructions and operations, high maintenance costs as well as clogging of the channels and low availability of water in some region. The most important challenge cited by the respondents was the high initial cost of setting up the hydroponics farming system in the area accounting to 60% of the total respondents. Many claimed that this high cost barred many prospective farmers in the area from adopting hydroponics farming. This is well illustrated and shown in the figure below

Figure 5. 9 Challenges



These findings correspond to the result of other similar studies. Many studies, especially those carried out in low-income countries show that the initial cost involved in setting up a hydroponic system significantly affects the decisions to invest in this type of farming. Specifically, Tripp (2014) noted that the high initial cost of investment is the major drawback to hydroponics farming. Some of the elements included in the initial investment cost include the cost of buying nutrients, pumps, heating system, hydroponic drip line, hydroponic timer, and hydroponic water system among others. The deduction is that the case of Kenya reflects the arguments advanced through the existing literature. In many cases, the resources required in setting up the system is beyond the reach of many farmers from low-income countries. In Kenya, the initial cost of hydroponics system depends on the number of trays. Other than these requirements, farmers seeking to adopt this type of farming must contract farmers with knowledge for installing the system. This partly accounts for the high cost involved.

Diseases and pests also accounts for a significant proportion of barriers reported by farmers towards the adoption of hydroponic farming. Controlling pests and diseases require effective management of the hydroponics system. This requires skills and resources. In particular, for effective management of a hydroponics system, there is the need for more focus on water quality management and bio-filter nitrification. These constitute some of the entry points for diseases and pests. Failure to manage these areas effectively is associated with increased chances of diseases and pests. According to Kibiti (2017), the cost of buying solutions to control pests is a major challenge for hydroponics especially in developing countries where farmers have limited capital and skills. A hydroponic system can be complicated to manage especially when operated in large scale. In such cases, other than the materials, there is the need for investment in workforce with the required skills. Some of the most instrumental skills in large scale implementation of the hydroponics system include knowledge in civil engineering design concepts and computer science. Knowledge in computer science, in particular, is instrumental in the design of automated system. The lack of these qualities in Meru County context has greatly impaired the development of hydroponics farming.

Another technical challenge that a farmer must deal with while investing in hydroponics system is nutrient balance. Using nutrient input effectively requires a lot of efforts and knowledge in the nutrient requirements of the plants grown. Nutrient balance significantly influences the quality of crops grown in the hydroponic system. According to Khan et al., (2018) maintaining nutrient balance can be achieved partly through an automated system. The use of an automated system is particularly important since it improves the efficiency and effectiveness of the system. The drawback is noted by Njima (2016) in that such a system would require significant capital investment. The observation in Meru is that the capital for most of the farmers is constrained, hence a challenge for the uptake of hydroponics farming in the region.

Clogging of the hydroponic system also accounts for a significant proportion of the challenges faced by farmers who adopt this system. Many farmers, especially those from low-income countries may face difficulties in managing the clogged systems. While clogged nozzles and pipes have reported significant challenges to farmers, new technologies offer great opportunities to overcome these challenges. Hydroponic systems present an opportunity that farmers seeking to maximize the use of their land or those that do not have access to large pieces of land can exploit. It is particularly preferred in urban farming where it can offer farmers an opportunity to produce without the need for a large piece of land, which may not be available in an urban environment.

5.9.1 Regression analysis model

From the onset, it is critical to note that the dependent variable in the analysis is the approbation of hydroponics farming. The variable is affected by multiple independent variables. This makes the multivariate regression analysis the most applicable analysis tool in this case. The independent variables in this model are nature of crops under hydroponics farming in Meru County, knowledge or awareness levels of the farmers, the inherent costs (initial costs and maintenance costs), and access to water by the farmers. The collected data was input in the SPSS V 21.0 package and the requisite operations were performed to yield the results of the regression model.

The study included R-Squared model which is a common statistic tool to determine the fitness of a model. The table below shows the variations in the dependent variable (hydroponics approbation) are attributable to the independent variables. This is confirmed by an R squared value = 0.876, implying that at least 88% of the hydroponics approbation can be explained by the combined predictor variables.

The results indicate that by holding all the other factors constant (the factors in this case being the cost of operations, the farmers level of awareness, cost of labour, cost of minerals and water and the cost of labour), the adoption of hydroponics farming in Meru county would be 0.002. The results also reveal that holding all the other independent factors constant or at Zero, increasing the ability to meet the initial cost of operations by one unit increases the rate of adoption of hydroponic farming in the area by 0.819 units. A unit increase in the level of farmers' awareness would consequently increase the rate of adoption of hydroponics farming by 0.817 units while an increase in the ability to afford the cost of labour by one unit would increase the adoption rate of hydroponics by 0.716 units. The regression results further established that a unit increase in the farmers ability to afford the mineral solution and water would lead to the adoption of hydroponics farming in Meru by 0.716 units while a similar increase of one unit in the farmer's ability to meet the cost of construction would lead to a 0.675 units increase in the rate of adoption of hydroponics farming in the area. From this analysis we can deduce that the farmer's ability to meet the initial cost of operations had the biggest independent impact on the rate of adoption of hydroponics farming in Meru.

It is important to observe that these statistics do not explain the contribution of individual variables to the dependent variable. The p-value of 0.002 presented in table 5.5, proves a highly significant regression relationship indicating that it was significant in the prediction of the effect of farmer awareness, cost of operations, types of crops grown, access to water and mineral solutions on the adoption of hydroponic farming in Kenya. The F-Value calculated was determined to be 5.8751 at the 5% significance level. The F critical was 2.1127. This indicates that the calculated F-Value is higher than the F-critical which ideally implies a presence of a significant model. In this case, the F- calculated is higher than the F critical (whose value = 2.1127), meaning that the model is significant. The hallmark observation is that the factors under review in the study influence the extent of hydroponics farming in Meru County, Kenya. Table 5.4 below presents the results of the regression model.

***Table 5. 4*-A multivariate regression analysis results indicating the relationship between the approbation of hydroponics farming as the dependent variable and the corresponding five independent variables.**

	Co-efficient	Std. Error	T-Ratio	P-Value
Constant	0.002	0.252	2.433	0.024
Cost of operations	0.819	0.081	11.762	0.000
Level of Awareness	0.817	0.086	2.543	0.001
Cost of Labour	0.716	0.081	2.145	0.003
Cost of Minerals and Water	0.716	0.065	2.657	0.004
Cost of Construction	0.675	0.076	2.452	0.000
R-squared	0.876			
Adjusted R-squared	0.234			

Source: Research Data (2020)

Based on table 5.4 above, it can be argued that there is a positive relationship between farmer awareness, cost of operations, the type of crops grown, access to the mineral solutions and water, and success of hydroponic farming in Kenya. The success of hydroponic farming in Kenya is the dependent variable while farmer awareness, cost of operations, access to the mineral solutions and water, and the type of crops that the farmers grow were run as independent variables. There was a significant constant term at 0.002 thus denoting a statistical significance, t (91) = 2.433, $p< 0.054$. The coefficient of hydroponic farming was 0.986 which too denoted a statistical significance, t (92) = 10.762, $p< 0.051$).

Based on this model, a positive relationship can be deduced between farmer awareness, cost of operations, the choice of crop grown and access to the mineral solutions and water, and success of hydroponic farming in the area under study. The results further show that the farmer awareness, cost of operations, the type of crops grown and access to water and mineral solutions influence the hydroponic farming success in Kenya on a constant of 0.002 and on an R-square of 0.876. The table also provides data that support the regression model ($Y=\beta 0 + \beta 1X1 +\beta 2X2 +\beta 3X3 +\varepsilon$) which can be summarized based on the model below

Success of Hydroponic farming in Kenya=Constant+ Initial Cost of operations β1+Farmers Awareness and trainings β2+ Cost of Water and Mineral β3+ Cost of Constructions β4 + 3ε

The regression analysis above, support the hypothesis employed in this study that the farmer awareness, cost of operations, the type of crops that farmers grow, access to the mineral solutions, and the access to water, influence the success of hydroponic farming in Kenya. The farmers also noted that the increased access to information on the new and improved varieties of crops and the ease of access to the mineral solutions provided by the private firms in the area had the biggest impact in informing their choice to adopt the hydroponics farming. They termed these private firms who benefit from selling then hydroponics system to them as playing an instrumental role in advising them on market prospects and new crop varieties a factor that also impacted on their choice to adopt and continue the hydroponics farming system. These findings confirm Kibiti's conclusion that access to information and capital(Initial cost of set up/construction) plays a major role in the adoption of hydroponics farming with the latter playing the leading role (Kibiti, 2017).

6 SUMMARY AND DISCUSSIONS OF THE FINDINGS

6.1 Introduction

This section summarizes the data findings gathered during the study. It includes a summary of the study objectives indicating the factors affecting the approbation of hydroponics farming as a means to mitigate and enhance the adaptation to the effects of climate change amongst small scale farmers using a case study of Meru County, Kenya. It also relates the results of this study to other past studies to find out the areas of agreements and any divergent opinions held by such studies in comparison to the findings of this research.

The specific objectives were to determine how access to capital, cost of production as well farmers awareness and the type of crops grown under hydroponic farming systems in Kenya. The specific summary of the study findings is shown in the discussion below.

6.2 Challenges facing the farmers

Based on the study findings, it was evident that the farmers noted a number of challenges that negatively affects their hydroponic farming activities. A major challenge experienced by almost all the farmers was the high initial cost of construction. The majority of the farmers noted that purchasing the hydroponic structure was expensive. This was mainly because there are few farmers embracing hydroponic farming in the region and thus the construction materials aren't readily available in the area. Additionally, there are very few institutions dealing with hydroponics farming in the country as well.

However, other key challenges that were noted by the farmers included high crop pests and diseases. These pests and diseases included trips, leaf miners and the powdery mildew. There were also various challenges associated with high clogging of channels as well as unstable availability of water in some regions. Some farmers also noted that lack of market to sell their produce was a challenge as well. The study found out that farmers were also experiencing high costs of nutrients solution. Some hydroponic structures also required the use of modern technological knowledge which majority of farmers do not have in the country.

6.2.1 Farmers awareness and actors involved in hydroponics farming

Based on the research results, a majority of farmers in Kenya are not aware of hydroponic farming systems. A few of the farmers who were aware of hydroponic farming models indicated that they did not get regular training from agricultural officers in the country. They argued that their main source of information about hydroponic farming was social media and the networks they have developed among other farmers in the region.

Some of the key players or actors that were sharing hydroponics farming in the region included the various government agencies, the private sector organizations as well as the NGOs. Despite this, it is evident that the majority of the farmers mainly gained training from the private sector and they pay an average of Kes.1, 000 for the service. Among the leading private companies offering training in hydroponics are Hydroponics Africa Limited and Grandeur Hydroponics. Most of the farmers confirmed having had contact with either of these companies. The companies operate model farms where farmers can visit and gain the necessary training. They also reach the farmers through workshops organized in the farmers' area. Some of the respondents in this study also noted that the private companies mentioned above linked them to better markets for their produce. They further claimed to have been linked to some credit institutions by the companies. Other farmers noted that these private companies enabled them adopt hydroponics farming by selling the system to them on instalment basis where the farmer paid some initial commitment fee and pays the other instalments as he or she continues to use the system. Extension staffs are few in the country and many farmers get training through online platforms such as Facebook and YouTube channels.

6.2.2 The type of crops grown by the farmers

The study found out that farmers in Kenya grow different types of crops under hydroponic systems. The majority of the farmers preferred crops with high returns such as fodder and spinach. However, the farmers also considered other types of crops such as Sukuma Wiki (Kale), peppers, onions as well as potatoes and cabbage. According to the results obtained in this study, it was evident that some farmers went to an extent of growing other rare types of crops such as fruit juice, bananas and tomatoes. A few of the farmers had embraced high value crops such as lettuce, broccoli, and strawberries. Despite their high economic returns, most of the farmers in the region decried a lack of market as these crop type were not popular in their local market.

One of the notably findings was that few farmers use their hydroponic structures to grow maize which is considered a stable food in the country. This is because the farmers considered only crops with short maturity period. The hydroponic structures adopted by the farmers also failed to support maturity of stable maize crops. As a result, many farmers in the region preferred growing fodder to feed their animals and to sell within the local market.

6.2.3 Sources of water used by the farmers

The study found out that the farmers were using different types of water sources. For example, some farmers were using surface water as the main source of water for their hydroponic farming activities. However, the farmers within rural areas were using dams and water from the rivers. The study also found out that some farmers were using tanks and water pangs to conserve water sources in their hydroponic farming models. There were also farmers who used underground wells as a source of water for their hydroponic farming and this means that water was not a big problem to the majority of the farmers in the region.

6.2.4 Cost of operations

The study found out that the farmers were experiencing high costs of operations. Cost of operations was high since the farmers have to cater for labour, constructing the hydroponics structures as well as purchasing fertilizers and pesticides. In some cases, the study found out that the cost of pesticides and fertilizers were high leading to reduced earnings to the farmers. Farmers also experienced high costs of operations in the process of purchasing mineral solutions and water, especially the hydroponics farmers who were living within urban centres.

6.3 Discussions of the findings in relation to past studies

The study findings confirmed other related past studies. This research established that the impact of climate change is escalating competition for the factors of production that include land, water and energy and this will hamper the world future food security and people should adopt alternative farming methods (Godfray et al., 2010). It was evident that the variability of rainfall patterns and low volumes and length of rain makes the conventional methods of crop production unsustainable and hence the need to look for viable alternatives such as the hydroponics farming which is not affected by such weather variations (Kabubo-Mariara & Kabara, 2018). It can be argued that the occasional weather variations as a result of the global climate change threaten the world's food security (Kang, Khan and Ma, 2009).

Moreover, the study results agree to a study done by Omambia and Ong'are (2019) which stresses the vulnerability of Kenya to climate change indicating that various sectors of the Kenyan economy have been adversely affected and this impact negatively on the country's socio-economic development. This means that the Kenyan government should consider drought challenges in their farming activities (Lee, 2015). The findings are also part of the conclusion made by Butler and Oebker (2016) who noted that the fast growth rate of hydroponics farming in agricultural production could stabilize future food production especially when the costs is controlled and the farmers are supported. Farmers need to grow high value crops such as citrus, broccoli, lettuce, and berries based on their short maturing periods and high economic returns (Lipper et al., 2014).

The findings also confirm the view made by FAO report in late 2019 indicating that future global food production depends on new technologies. Agriculture will provide employment, income and food security to a majority of Kenyans (FAO, 2019). The study results also confirmed the view by Lee & Lee (2015) who pointed out that hydroponics farming should be done in a highly controlled operation in order to culminate in the provision of a well-designed conducive environment for the plants to thrive in thus increasing their productivity as compared to their counterparts produced conventionally. The findings also supported the view that high initial costs, lack of support and poor climate is a big challenge to hydroponic farmers (Maharana & Koul, 2011). Additionally, the findings noted that high maintenance and running cost are big challenges facing hydroponic greenhouse farmers (Tripp, 2014). The majority of the workers lack technical expertise as was reported in a study done by Khan et al., (2018). It also established that limited high potential agricultural land and the type of crop grown also form part of the factors that determine the hydroponics farming in the region. This is in line with the findings of a similar study conducted by Kibiti (Kibiti, 2017).

7 CONCLUSIONS

From a careful analysis of the study, it can be concluded that there are various factors that influence hydroponic farming in Kenya. One of the key factors that all hydroponic farmers should consider is the initial cost of operations and the cost of fertilizers and pesticides. The study also concluded that lack of money and market to sell the products is a big challenge to many farmers in Kenya. Majority of the farmers failed to adopt modern technologies in their hydroponics activities since they lacked the requisite training and awareness.

The study findings indicated that majority of the farmers engage in credit facilities to procure modern farm inputs which include seeds of high yields and quality as well as pesticides and fertilizers. However, many farmers in the region are small scale farmers. This means that they grow variety of crops for home use and end up having low economic returns from their ventures. This is as a result of their limited capacity to secure credit for a bigger hydroponics system that could accommodate more crops for higher returns. The high cost of high value crops such as strawberries and lettuce also keep them off their limits. Due to this, the study concluded that farmers should grow fast maturing high yield varieties and invest in large scale hydroponic farming to gain high returns in order to benefit from the economies of scale. The study recommends that they approach the private companies offering hydroponics systems in the area for an instalment arrangement and advice on better market prospects.

The study also concluded that hydroponic farming is one of the lucrative ventures in Kenya and farmers should get training on how to invest in high yielding crops. This is because farmers practising higher scale hydroponics (the 8 meters by 30 meters) reported annual profits averaging to up to Kes. 600,000. Such profit margins could be extended further by the adoption of more than one hydroponics farming structure, automation of their current systems for improved yields, and planting of high value crops. These high value and fast maturing crops varieties could include strawberry, Lettuce, broccoli and fodder. They should liaise with the private organizations operating the hydroponics structure management in the area for external markets. From the findings, it can also be concluded that hydroponic farming is not well developed in the country and the government has failed to support it sufficiently. Many farmers mainly learn about hydroponic farming from social media platforms as well as from private sector organizations. Based on the study findings, it can be concluded that cost of operations, access to water, fertilizer, pests, types of crops grown as well as farmers awareness levels should be considered in the process of initiating hydroponic farming.

7.1 Recommendations

The study findings manifested that many farmers in Meru County- Kenya experience various challenges such as high incidences of pests and diseases, high initial cost of operations as well as clogging of channels and low availability of water to irrigate some of the crops. The farmers also indicated lack of market to sell their products as one of the challenges. From the above challenges, the study recommends a number of policies and programs that can be adopted by the farmers within the region to improve and promote their hydroponic farming activities and programs. Some of the programs and policies that the farmers can adopt include the following:

7.2 Collaborating with Stable financial institutions

The collaboration with stable financial institutions can help to provide the farmers with credit and improve their agricultural activities. This will help them to invest in stable hydroponic farming activities with high returns. Additionally, it is evident that the country has a number of financial institutions such as Banks and Sacco's that can advance the farmers loans to improve their hydroponics farming activities. With enough financial support, the farmers can invest in stable hydroponic farming systems and improve their returns in the long run.

7.3 Farmers should get proper training on hydroponics farming

The government of Kenya should introduce effective training methods that can attract more farmers to adopt hydroponics farming plans in the country. With effective training from agricultural extension officers from the government, many farmers will feel encouraged to adopt hydroponics farming. This is because they will have the ability to learn more about the hydroponic farming. Effective training will also give the farmers the opportunity to understand which type of crops they can grow and get high returns within a short time.

7.4 Adoption of modern technology to control pests and diseases

With high levels of pests and diseases affecting the majority of the farmers, it is imperative that the government introduce new policies that will encourage farmers to adopt modern technology in controlling the pests and diseases affecting their operations. The government should also introduce modern water management models to encourage farmers to conserve water and improve their hydroponics farming activities. The use of modern technologies will also help to reduce the clogging of the hydroponics structures and water channels. The farmers should also embrace modern technologies in improving the greenhouse farming as well as their hydroponics farming and hanging garden models. This will ensure maximum production with the available space among different farmers.

7.5 Growing different crops with high returns

A major challenge facing the farmers in Kenya is the growing of crops with low economic return. To reduce this challenge, the farmers should grow crops with high returns such as strawberries and flowers. It is also imperative that the farmers grow crops with short maturity period to maximize their returns. This may include growing of new breeds of fodder. Importantly, the farmers should work closely with different research centres within the country to learn on the best crops that can improve their profitability.

7.6 Venturing into new markets

The farmers should shift their focus from the local market and grow crops suitable even for external markets. Such a move could not only expand their market prospects but would also open up opportunities for them to produce high value high yield crops that are not necessarily popular in the area. They should also engage in contract farming as this could guarantee a ready market for their produce. Arrangements should be made to help sensitize the farmers on the international market needs and policies made to help them reach such markets effectively.

7.6 Suggestions for further Studies

The primary objective of this research was to establish the factors that impact on the adoption of hydroponic farming system as a mitigation and adaptation factor to the threats and challenges of climate change amongst the small scale farmers in Meru County, Kenya. This means that the study mainly focus on hydroponics farming challenges in Kenya from a climate change perspective. However, it is important that future studies be done on how hydroponics farming systems can be used to promote global food security. Additionally, future studies should provide a comparative study to compare the stability of hydroponics farming in developed and developing countries. This can help shape the future of hydroponics farming, especially within developing countries such as Kenya.

8 REFERENCES

Agribusiness – Miramar International College. (2019). https://mic.ac.ke/agribusiness/

Ayele, S., Duncan, A., Larbi, A., & Khanh, T. T. (2012). Enhancing innovation in livestock value chains through networks: Lessons from fodder innovation case studies in developing countries. *Science and Public Policy*, *39*(3), 333–346.

Berg, B. L., & Lune, H. (2012). Qualitative research methods for the social sciences (internat. Ed. Ed.). *Boston [Ua]: Pearson Education*.

Brand Kenya. (2018). Facts About Kenya. *Brand Kenya*. https://brandkenya.go.ke/facts-about-kenya/

Bryman, A. (2012). *Social research methods* (4th ed). Oxford University Press.

Creswell, J. W., & Creswell, J. D. (2018). *Research Design:Qualitative,quantitative,and mixed methods approaches* (Fifth). sage.

Creswell, J. (2015). *30 essential skills for the qualitative researcher*. Los Angeles, CA: SAGE

Cristina, M., Jacqueline, P., Francesco, P. (2010). A Brief Review of Systems Theories and Their Managerial Applications. Service Science 2(1-2):126-135.

Daniels, F. S., & Landers, D. M. (1981). Biofeedback and shooting performance: A test of disregulation and systems theory. *Journal of Sport Psychology*, *3*(4), 271–282.

FAO. (2019). *Kenya at a glance | FAO in Kenya | Food and Agriculture Organization of the United Nations*. http://www.fao.org/kenya/fao-in-kenya/kenya-at-a-glance/en/

Fodder systems. (2019). *Hydroponics Kenya*. Retrieved 1 October 2019, from https://hydroponicskenya.com/products/fodder-systems/

Fowler, F. J. (2014). *Survey research methods* (Fifth edition). SAGE.

Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., Pretty, J., Robinson, S., Thomas, S. M., & Toulmin, C. (2010). Food security: The challenge of feeding 9 billion people. *Science*, *327*(5967), 812–818.

GOK. (2013). County Integrated Development Plan: Meru County. Government of Kenya, Nairobi, Kenya.

GoK. (2014). Agricultural Sector Development Support Program. Government of Kenya, Ministry of Agriculture Livestock and Fisheries.

Grossoehme, H. (2014). Overview of qualitative research. *Journal of Healthcare Chaplain*, 20, 109-122

Hydroponics Africa Limited | KCIC. (2018). https://www.kenyacic.org/content/hydroponics-africa-limited

Jones, J. B. (2005). *Hydroponics: A practical guide for the soilless grower* (2nd ed). CRC Press.

Kabubo-Mariara, J., & Kabara, M. (2018). Climate change and food security in Kenya. In *Agricultural Adaptation to Climate Change in Africa* (pp. 55–80). Routledge.

Khan, F.A., Kurklu, A., Ghafoor, A., Ali, Q., Umair, M., Shahzaib, (2018). A Review on Hydroponic Greenhouse Cultivation for Sustainable Agriculture. *International Journal of Agriculture, Environment and Food Science*, 2(2), pp.59-66.

Kibiti. (2017). *Factors Influencing Adoption of Urban Hydroponic Farming. A Case of Meru Town, Meru County, Kenya*. 67.

KNBS. (2018). *Kenya National Bureau of Statistics*. Kenya National Bureau of Statistics. https://www.knbs.or.ke/

Lee, S., & Lee, J. (2015). Beneficial bacteria and fungi in hydroponic systems: Types and characteristics of hydroponic food production methods. *Scientia Horticulturae*, *195*, 206–215.

Lipper, L., Thornton, P., Campbell, B. M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., & Henry, K. (2014). Climate-smart agriculture for food security. *Nature Climate Change*, *4*(12), 1068.

Maharana, L., & Koul, D. (2011). The emergence of Hydroponics. *Yojana* (June). 55: 39-40.

Meru County Government. (2020). Meru County Government. http://meru.go.ke/content.php?com=37&com2=54&com3=

Michie, D. (1982). *Introductory readings in expert systems* (Vol. 1). CRC Press.

MoALF. (2016). Climate Risk Profile for Meru. Kenya County Climate Risk Profile Series. The International Center for Tropical Agriculture (CIAT) and the Kenya Ministry of Agriculture, Livestock and Fisheries (MoALF), Nairobi, Kenya

Njima, P. M. (2016). An assessment of factors influencing production of hydroponics fodder among smallholder dairy farmers in Kiambu sub county, Kenya. *A Research Project Report Submitted in Partial Fulfilment for the Requirements of the Award of the Degree of Master of Arts in Project Planning and Management, University of Nairobi, Kenya*.

Ong'are, D. W., & Omambia, A. N. (2019). Building Pastoral and Agro-Pastoral Community Resilience Against Drought in the Context of the Paris Agreement: The Case of Isiolo County, Kenya. *Handbook of Climate Change Resilience*, 1–22.

Pahl-Wostl, C. (2007). The implications of complexity for integrated resources management. *Environmental Modelling & Software*, *22*(5), 561–569. https://doi.org/10.1016/j.envsoft.2005.12.024

Parkin, A. (1980). Systems analysis by entity-relationship modelling: A case study. *Computer Bulletin, Series II*, *26*, 12–14.

Polit, F., & Beck, T. (2014). *Essentials of nursing research appraising evidence for nursing practice.* Lippincott Williams & Wilkins Philadelphia.

Silver, G. A., & Silver, M. L. (1989). *Systems analysis and design*. Addison-Wesley New York.

Singh, K. (2007). *Quantitative social research methods*. Sage Publications.

Singh, S., & Singh, B. (2012). Hydroponics – A technique for cultivation of vegetables and medicinal plants In. Proceedings of 4th Global conference on Horticulture for Food, Nutrition and Livelihood Options Bhubaneshwar, Odisha, India. p. 220.

Takakura, T. (2014). Greenhouse production in engineering. *Mathematical and Control Applications in Agriculture and Horticulture*, 5, p.19.58

Tripp, T. (2014). *Hydroponics advantages and disadvantages: Pros and cons of having a hydroponic garden*. Speedy Publishing LLC.

Žukauskas, P., Jolita, V., & Regina, A. (2018). Philosophy and Paradigm of Scientific Research, Management Culture and Corporate Social Responsibility. Retrieved on 20 April 2020 from: https://www.intechopen.com/books/management-culture-and-corporate-social-responsibility/philosophy-and-paradigm-of-scientific-research

9 Appendices

Appendix 1

Questionnaire

DATE:

ADDRESS:

TELEPHONE:

TIME:

Factors affecting the adoption of hydroponics farming system in Meru-Kenya

This study is conducted as a partial fulfilment of the degree of masters in International development studies at the Norwegian university of life sciences. Your kind contribution in a way of answering this questionnaire will be highly appreciated as it will greatly enable me in the achievement of the study objectives. Kindly note that your privacy will be highly secured and a feedback will be sent back to you for a final review after the data analysis for your confirmation should you find this necessary. Should you have any reservations towards answering any part of the questionnaire kindly feel free to raise your objections or comments about the same.

1. Age

18-25	
26-35	

36-45	
45-55	
Above 56	

2. Gender

Male	
Female	
Other	

3. In which way did you learn about the hydroponic farming system and why did you adopt it?

4. How has hydroponic farming system developed in your area? How many farmers have adopted it?

5. What is the cost of operating the hydroponic system based on the following parameters?

Parameter	Amount(Kshs.)
Capital Input(Initial cost of the system materials)	
Labour Input	
Cost of the Mineral solution/nutrients	
Cost of fertilizer and Pesticides	
Cost of Water	

Cost of Construction	
Other costs(specify)	

6. What type of crops do you grow and what are their yield levels per season/harvesting intervals? Any preferred crop type and why?

7. How do you sell the crops? Is there a ready market for your crops? What are your profit/Loss Margins?

8. Do you get any support from the Agricultural extension officers? Who else support you in the development and operation of the hydroponic system?

9. What would you term as the major challenges and constraints facing hydroponics farming in Meru?

10. On a scale of 1-5 (One being the least satisfied and 5 being the most satisfied) how satisfied are you with hydroponic farming system as compared to other conventional farming methods?

1	2	3	4	5

For further clarification do not hesitate to contact

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Olav M.Troviks vei 18, 0864 Oslo-Norway

Email:fredmwenda2011@gmail.com

Tel: +4793932104

APPENDIX 2

HYPOTHESIS OF THE STUDY

				Factors affecting the adoption of hydroponics farming system in Meru-Kenya
		VARIABLES OF THE STUDY		
		INDEPENDENT VARIABLES		
		· Initial Cost of Construction		
		· Crop Diseases and pests		
		· Availability of water and Market		
		· Type of Crops grown		
		· Farmers awareness levels		
		DEPENDENT VARIABLE		
		· Adoption of Hydroponics Farming		
		HYPOTHESIS		
		· Initial cost of constructions, crop diseases and pests, availability of water, types of crop grown and farmer's awareness levels are the main factors affecting adoption		

		of hydroponics farming in Kenya		

APPENDIX 3

VARIABLES OF THE STUDY AND CODING FRAMEWORK

<u>VARIABLES OF THE STUDY</u>

INDEPENDENT VARIABLES

- Initial Cost of Construction
- Crop Diseases and pests
- Availability of water and Market
- Type of Crops grown
- Farmers awareness levels

DEPENDENT VARIABLE

- Adoption of Hydroponics Farming

HYPOTHESIS

- Initial cost of constructions, crop diseases and pests, availability of water, types of crop grown and farmer's awareness levels are the main factors affecting adoption of hydroponics farming in Kenya

Factors affecting the adoption of hydroponics farming system in Meru-Kenya

Key Variables

1. **Age**

   18-25-1

   26-35-2

   36-45-3

   45-55-4

   Above 56-5

2. **Gender**

   Male-1

   Female-2

3. **Cost of operating the hydroponic system**

   Capital Input-1

   Labor Input-2

   Cost of the Mineral solution/nutrients-3

Cost of fertilizer and Pesticides-4

Cost of Water-5

Cost of Construction -6

Other costs (specify)-7

4. Types of crops grown

Tomato-1

Strawberries-2

Fodder-3

Carrots/peas=4

Spinach/Sukuma wiki-5

Lettuce-6

Capsicum/sweet peppers-7

Onions-8

Fruits-bananas -9

5. Challenges facing hydroponic farmers

Crop diseases and pests-1

Clogging of Channels-2

High maintenance costs-3

High Initial Cost of Constructio4

Low Availability of water and Marke-5

Variable	Coding	N
Age	Exact Number	230
Gender	Male=1, Female=2	230
Initial Cost of Operations	Capital Input=1 Labor Input=2 Cost of the Mineral solution/nutrients=3 Cost of fertilizer and	230

	Pesticides=4 Cost of Water=5 Cost of Construction =6	
The Types of Crops Grown	Tomato=1 Strawberries=2 Fodder=3 Carrots/peas=4 Spinach/Sukuma wiki=5 Lettuce=6 Capsicum/sweet peppers=7 Onions=8 Fruits-bananas =9	230

Challenges facing Hydroponic farmers	Crop diseases and pests=1 Clogging of Channels=2 High maintenance costs=3 High Initial Cost of Construction=4 Low Availability of water and Market=5	230

APPENDIX 4

CODED DATA-RESPODENTS ANSWERS TO THE QUESTIONARRE

						Factors affecting the adoption of hydroponics farming system in Meru-Kenya		
		KEY VARIABLE						
S/No.	**Gender**	**Age**						
			Cost	**Crops**		**Challenges**		
1	**1**		4	1		1		
2	**2**		5	2		2		

3	**2**		1	3		3		
4	**2**		2	1		2		
5	**2**		7	4		4		
6	**2**		3	7		1		
7	**2**		1	9		2		
8	**2**		3	5		5		
9	**2**		7	1		5		
10	**2**		4	6		5		
11	**2**		6	3		5		
12	**1**		6	1		5		
13	**2**		6	1		5		
14	**1**		6	1		5		
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