SOCIAL, ECONOMIC AND INSTITUTIONAL FACTORS INFLUENCING DRIP IRRIGATION TECHNOLOGY UPTAKE AMONG SMALL SCALE HORTICULTURAL FARMERS IN SUBUKIA SUB COUNTY NAKURU COUNTY, KENYA

BY

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A THESIS SUBMITTED TO THE SCHOOL OF AGRICULTURE AND NATURAL RESOURCES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER OF SCIENCE DEGREE IN AGRICULTURAL ECONOMICS AND RESOURCE MANAGEMENT

MOI UNIVERSITY

2021

DECLARATION

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DEDICATION

This thesis is dedicated to all those who are dear to me: To my supervisors namely Dr. Ernest Saina and Dr.Winrose Chepng'eno

My parents Harrison, and Ruth. My mother, who taught me persistence and perseverance, and to my father, who taught me that there is always a better solution. My wife Mercy, James, Onesmus and Levi, Chelsea my daughter and sons for their encouragement, material and moral support throughout the writing of this thesis.

ACKNOWLEDGEMENTS

Firstly, I am obliged to register my sincere thanks to my thesis supervisors, Dr. Ernest Saina and Dr. Winrose Chepng'eno for their tireless efforts and insights in the progress of this study. Their constructive criticisms, valuable suggestions and guidance were integral ingredients in the course of this study. My thanks also go to the Ministry of Agriculture staff, Subukia for assisting me to conduct this research. I am particularly indebted to the Sub County Agriculture Officer, Subukia for his assistance. I shall not forget to acknowledge Moi University Library staff who assisted me to obtain some of my major sources of the literature review, for which I am so grateful to them. Above all, I am greatly indebted to my parents, wife, children and siblings who through word and deeds sacrificed so much for my studies and to ensure that all remained afloat and for always being a source of comfort and encouragement throughout my education. Finally, I thank God for sparing my life and giving me joy and support to be able to complete this thesis.

ABSTRACT

The importance of irrigation in increasing agricultural productivity in arid and semi arid areas in Kenya cannot be underscored. Several efforts and resources from both the government and donor community have been expended for promotion of irrigation technology to increase food production over the years in Subukia, Nakuru County. Despite this investment, adoption levels have remained low. Therefore, this study aimed at analyzing the social, economic and institutional factors influencing adoption of drip irrigation technology among smallholder horticulture farmers in Subukia. The study was based on rate adoption theory. The target populations for the study were all the smallholder horticultural farmers in Lari Wendani irrigation scheme, Subukia Sub County, comprising of both adopters and non-adopters. A census study was used, since the total numbers of farmers in the scheme are 277.Data was collected by use of structured questionnaires. Descriptive measures and logit model were used for data analysis. Descriptive statistical analysis showed the demographic and socio-economic characteristic of the households. In identifying the reasons for poor technology adoption among smallholder horticultural farmers in Subukia, the study provides important information that can contribute to policy formulation. Results showed that social factors, such as farmer experience $\beta = 0.5607$,$p = 0.0000$,age $\beta = 0.1125$, $p = 0.000$ economic factors , off farm income $\beta = 0.0254$, $p = 0.000$, farm size $\beta = 0.0581$, $p = 0.0411$ and institutional factors such as, access to credit $\beta = 0.0608$,$p = 0.0040$, access to extension services $\beta = 0.0879$, $p = 0.0000$, land tenure $\beta = 0.0098$, $p = 0.0020$ and source of extension knowledge $\beta = 2.5914$, $p = 0.0000$ significantly affected adoption of drip irrigation technology among small scale horticultural farmers in Subukia, Nakuru County. It is recommended that Government and other stakeholders should help in developing institutional interventions to encourage adoption of drip irrigation for instance by employing more extension personnel. Key policy principles in promoting adoption of drip irrigation should clearly focus on long term strategies to aggressively invest in agricultural extension but also make credit easily available to farmers. Another policy recommendation is for the government to provide arrangement that will enable secured land tenure such as land use planning and good land governance by both institutions of state and that of society as an incentive for successful adoption and scaling-out of drip irrigation technology by farmers in Subukia, Nakuru County.

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OPERATIONAL DEFINITION OF TERMS

Adoption: The act or process of taking up something new or different; the act or process of giving official acceptance or approval to something. In this case is uptake of drip irrigation technology.

Age: This refers to the number of length of time during which a being or thing has existed; length of life or existence.

Communication: is a process in which participants create and share information with one another to reach a mutual understanding" (Rogers, 1995).

Diffusion research: Diffusion research centers on the conditions which increase or decrease the likelihood that a new idea, product, or practice will be adopted by members of a given culture. Diffusion of innovation theory predicts that media as well as interpersonal contacts provide information and influence opinion and judgment (Rogers, 1995).

Diffusion: is the "process by which an innovation is communicated through certain channels over a period of time among the members of a social system". An innovation is "an idea, practice, or object that is perceived to be new by an individual or other unit of adoption". (Rogers, 1995). "

Exposure to Extension Service: This is whether the farmer has received extension advice or not.

Extension: A source of information about better farming practices. Frequent extension contact positively impacts on adoption of an innovation.

Gender of household head: A person's inner sense of being male or female

Drip irrigation technology: Drip irrigation is a controlled, slow application of water to soil over a long period of time, usually lasting several hours. The water flows under low pressure through plastic pipe/tubing laid along each row of plants. It reduces water loss by up to 60 percent. Flow rate needs to be adjusted so that there is no flooding or runoff.

Household: A household would be considered as a person or group of related or unrelated persons who live together in the same dwelling unit(s)

Income of household: The flow of cash or cash-equivalents received from working. Income enables the household to access and purchase the technology

Level of Adoption: The proportion of number of farmers who will have adopted drip irrigation technology to the total number of farmers worked out as a percentage

Smallholder horticulture farmer: In this study, this is a farmer who owns land size not exceeding 1 hectare. Labor is provided by the household.

Uptake: The action of taking up or making use of something that is available.

LIST OF ABBREVIATIONS AND ACRONYMS

BLRM	Binary Logit Regression Model
CO_2	Carbon IV oxide
DOI	Diffusion of Innovation Theory
FAO	Food Agriculture Organization
GDP	Gross Domestic Product
GOK	Government of Kenya
Ha	Hectares
HCD	Horticultural Crops Directorate
HYV	High Yielding Varieties
ICRA	International Center Research Association
IFPRI	International Food Policy Research Institute
IPM	Integrated Pest Management
KES	Kenya Shillings
KHDP	Kenya Horticultural Development Program
KNBS	Kenya National Bureau of Statistics
MOA	Ministry of Agriculture
MT	Metric Tonnes

CHAPTER ONE: INTRODUCTION

1.1 Overview

This chapter covers the background information of the study, problem statement, objectives of the study, research hypotheses, and significance of the study. The last part in this chapter presents the theoretical scope and application of the study.

1.2 Agriculture in Kenya

In Kenya, as in many parts of the sub Saharan Africa, agriculture is the mainstay of the livelihood of her citizens. Over 75% of the population of Kenya relies heavily on subsistent farming and 52% of her entire workforce directly practices small-scale farming including pastoral activities (Maina & Maina, 2012). Small-scale/subsistence farming produce accounts for over 75% of the entire agricultural output and over 70% of the marketed agricultural produce in Kenya. Sixty-six (66) percent of the country's manufacturing sector is agro based. These statistics go to show the importance of small-scale farming to Kenya's economy. The same statistics underscore the importance of focusing on this sector with interventions geared towards achieving success (Muthui, 2015).

The country enjoys a variety of climates and soils but less than 20% of the land size is considered arable under rain fed condition. The remaining 80% is classified as arid and semi arid lands (ASALs) and experiences perennial water shortage which is a major constraint to agricultural production. Due to population pressure in the high and medium potential areas, people whose livelihoods traditionally depended on subsistence farming have since moved to the ASALs and intensively cultivated them.

Cultivation in this fragile ecosystem has not been sustainable without external inputs such as water and nutrients, (Okumu, 2004). According to Okumu, between the mid-1960s and the mid-1980s, parastatal irrigation agencies were established and irrigation infrastructure was installed in significant tracts of land. Besides installing infrastructure and providing support services, many agencies took on responsibility for purchasing inputs, selling outputs and organizing production processes, in fact taking on the character of 'command-and control' operations, with smallholder farmers largely treated as laborers.

According to National Irrigation Board Mid Term Plan (MTP) 2013-2017, to achieve vision 2030 for Kenya, Irrigation is critical to increasing agricultural productivity. In this regard, incentives will be provided for farmers to invest in energy and water-efficient irrigation systems and technologies. Further the existing schemes need to be rehabilitated and expanded while new ones will be put place.

Both the Kenya vision 2030 and the Second Medium Term Plan (MTP) 2013-2017 underscores the important role that irrigation is expected to play in improving agricultural productivity and meeting Kenya's food security needs. The MTP estimates that irrigation can increase agricultural productivity four-fold and depending on the crops, multiply incomes by up to ten times. To promote agricultural productivity, the government plans to increase the area under irrigation and drainage from the current 140,000 ha to 1.2 million ha in 2030, an expansion of irrigation acreage by 48,000ha (34%) per year (AASR, 2016). The government targets to exploit the agricultural potential in ASAL areas by putting an additional 600,000 ha under irrigation.

1.2.2 Technology Adoption

Many factors can affect a farmer's decision to adopt a new technology in the production system. In developing countries, this subject has been widely addressed because of the importance agriculture to the composition of household incomes. In Florida, the age of the producer and the in-grove spatial variability presented a negative and positive impact, respectively, on the likelihood of adoption of precision farming technologies in citrus orchards (Sevier and Lee, 2004). Lapar and Ehui (2004) identified that small producers who have higher levels of education, higher incomes and access to credit are more likely to adopt dual-purpose forages in Philippine. According to Ogada*et al.,* (2014) the joint adoption of inorganic and improved maize varieties in Kenya was influenced by the use of manure, access to credit, distance to input markets, secure tenure, education and gender of the household head, cultivated area, drainage of the plots, and expected yields.

With respect to irrigation technologies, the literature distinguish mainly two stages of the adoption process. The first was related to the primary adoption in which the producer did not use previously any type of irrigation. The second was related with the change of an irrigation system for another; usually more efficient in the use of water. This second stage of adoption especially addressed in countries or regions with water resource scarcity problems and environmental degradation.

Techniques of irrigation vary across crops; common methods included surface irrigation (furrow or flood), overhead sprinklers, trickle irrigation (drip or buried), micro-sprinklers, Moneymaker pumps, and direct can watering (Kinyua, 2009). Research indicates that the kind of irrigation system used depends greatly on the type of farmer, size of farm, and range of operation, as well as the drought tolerance of particular plant standings (Uddin, Bokelmann, & Entsminger, 2014).

Adoption also varied according to initial investment costs and was sometimes related to the gender of the producer. Tumbo*et al.,* (2011) observed that men usually had more power to make adoption decisions that involved general changes in farm topography; women could not have this power because of lack access to and/or ownership of land. In any case, smallholder farmer support was vital in order to boost adoption of new irrigation technologies.

1.2.3 Agricultural Technology Adoption

It is estimated that 76% of the population in Kenya live in rural areas, mainly as small-scale farmers, among the many factors that contributed in the growth of agricultural productivity; technology is the most important (Kinyua, 2009). The rate of adoption of a new technology is subject to its profitability and the degree of risk and uncertainty associated with it and is highly influenced by the capital requirement, agricultural policies and socio-economic characteristics of the farmers, RoK (2015).

The question of adoption and non adoption is important, however, intensity of adoption is actually the most important criterion in the adoption process. According to Rogers (1995), there are several factors affecting farmer's decision to adopt irrigation technologies. Extension creates awareness on existence of irrigation technology, the farmers assess whether the technologies are acceptable to them given their land sizes, crops grown, education, experience, labour availability or demand, expected improvement in fertility, availability of credit facilities, input cost and other factors.

According to Singh (2020)the decision to determine whether it is feasible and profitable for farmers to adopt and implement the irrigation technology on their farms may be instantaneous, that is they can adopt immediately in the same year when the technology is introduced or it can take several years depending on socio-economic factors such as education, frequency of extension contact, technology input prices and literacy levels.

1.2.4 Agricultural Irrigation Technology

Reducing vulnerability to rainfall failure shocks and variability of production is extremely important for subsistence farmers. Fewer or less severe shocks mean the household is able to maintain proper consumption levels and is less likely to deplete savings or productive assets (tools and livestock) to cope with a shock. Reduced vulnerability enables poor farmers to maintain their productive assets and avoid indebtedness of credit used for consumption (Burney *et al.*, 2010).

According to Muthui (2015), irrigated land is only 3.6 per cent of total cropland on the continent compared with the world average of 18.4 per cent. The development of irrigated agriculture is highest in COMESA (14.4 per cent of arable land), possibly due to the large irrigation projects in Egypt and Sudan. In Kenya, irrigation accounts for only 1.7 percent of the total land area under agriculture, but contributes 3 percent to the GDP and provides 18 per cent of the value of all agricultural produce demonstrating its potential in increasing agricultural production and productivity.

Irrigation is linked to poverty reduction through its effect on crop production and increased farm income. Adequate water supply to crops increases the production available for household consumption and or sale. Irrigation can enable farmers to have a second and sometimes a third crop planting season, thus increasing income for the farmer. In addition to increasing overall production, irrigation increases the reliability and consistency of production (Smit, 2003).

Irrigation enables the farmer to control the available water throughout the growing season which boosts production and reduces exposure to water shortfalls or seasonal droughts. In arid and semi-arid areas where rainfall is inadequate, unreliable, or incorrectly timed, reducing the farmer’s dependency on unsuitable weather patterns is important for the best production. Irrigation technologies in Kenya dates back to some 400 years, longer than that of most countries in East and Southern Africa. Today, it is worth noting that Kenya is well ahead of other countries in the sub-region in utilizing low-cost technologies for small-scale irrigation, defined here as irrigation on small plots where farmers have the major controlling influence and using a level of technology which farmers can effectively operate and maintain (Carter, 1994).

Kenya has an estimated irrigation potential of 1.3 million ha and a drainage potential of 600,000 ha. Currently, 114,600 ha of irrigation and 30,000 ha of drainage have been developed. Of the available irrigation potential, 540,000 hectares can be developed with the available water resources, while the rest of the area will require water harvesting and storage. The developed irrigation potential can be categorized into the following three main types: smallholder schemes, 49,000 hectares, (43 per cent); public/national schemes, 20,600 hectares, (18 per cent); and, private schemes, 45,000 hectares (Randall, 2012). The remaining potential of over 424,400 hectares and 570,000 hectares of irrigation and drainage calls for increased focus to unleash this potential (ASDS, 2010-2020).

1.3 Problem Statement

In the study area, Lari Wendani irrigation scheme farmers use irrigation methods which use lots of water leaving the river with low volume or dry downstream during the dry period. Igwamiti River is the main water source. They are not able to have enough water during this period. Downstream are pastoralists who do not get enough water for their livestock and domestic use due to over abstraction from the river during the period. If the farmers upstream would adopt water efficient irrigation method (drip irrigation) it goes a long way increasing their production per unit area and downstream people would get enough water during dry period. However, in spite of some indications of improvements on the ground, in the study area there are not sufficient studies under-taken assessing the adoption decision of farmers. Given that the main driver for the promotion of drip irrigation in Kenya has been the provision of financial subsidies from the government. The present study focuses primarily on Subukia Sub County the evidence drawn upon and the conclusions drawn from the study expectantly is expected to have general applicability for other regions of the county as well.

1.4 General Objective

The main purpose of this study was to analyze social, economic and institutional factors influencing adoption of drip irrigation technology among smallholder horticultural farmers in Subukia Sub County, Nakuru County, Kenya

1.4.1 Specific Objectives

1. The study addressed the following specific objectives;
2. To determine the effect of social factors (age, gender, education level and farm experience and family size) on adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County, Kenya
3. To determine the effect of economic factors (farm income, land size, and off farm income) on adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County.
4. To determine the effect of institutional factors (access to credit, availability of extension service, land tenure, extension services and frequency of extension visits) on adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County.

1.5 Hypotheses of the Study

The following hypotheses were tested:

H_{01}: Social factors (age, gender, and education level, farmer experience and family size) do not significantly influence the adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County.

H_{02}: Economic factors (farm income, farm size, off-farm income) do not significantly influence the adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County.

H_{03}: Institutional factors (access to credit, availability of extension service, frequency of extension visits, land tenure and source of extension knowledge) do not significantly influence the adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County.

1.6 Significance of the Study

Despite the benefits of irrigation, adoption of the technology has been very low in Africa. According to FAO only 6 percent of the cultivated land in Africa is irrigated, in contrast, 35 percent of the cultivated land in Asia is irrigated. In response to the potential benefits of irrigation and the low adoption rates in rural areas, especially in Africa, there are many organizations, governmental and non-governmental promoting small-scale irrigation technology.

The irrigation projects implemented in developing countries provide a wide variety of information, services and financial assistance; however, very little rigorous evaluation has been conducted on the actual factors influencing adoption among both participating and non-participating households. The findings provide useful insights that can inform the implementation of similar projects in Nakuru County and lessons to be learnt shared across similar initiatives in Kenya.

The findings are also crucial in informing current irrigation technology adoption decision making processes among small scale farmers within a particular social context, identification of constraints (socio-economic and institution) that hinder wider adoption of irrigation technology. It will also provide the basis to work on their solutions and improve technology adoption among small scale farmers.

1.7 Scope of the Study

The study covered only Subukia Sub County. This was mainly due to limitation of resources in terms of time and funds required to undertake the study on a larger scale. The study targeted all small-scale farmers in the area, and sample size was 277 households. The key issues in this study were social, economic and institutional characteristics of smallholder drip irrigation farmers. Structured questionnaire was used to collect data. To deal with the problem of illiteracy of respondents, there was training and close supervision of enumerators so as to eliminate distortion of information and improve on the quality and reliability of data that were collected.

1.8 Theoretical Scope and Application of the Study

The current study is diffusion research and has focused on five areas: (1) the characteristics of an innovation which may influence its adoption; (2) the decision-making process that occurs when individuals consider adopting a new idea, product or practice in the current study drip irrigation; (3) the characteristics of individuals that make them likely to adopt an innovation (drip irrigation); (4) the consequences for individuals and society for adopting an innovation; and (5) communication channels used in the adoption process.

CHAPTER TWO: LITERATURE REVIEW

2.1 Overview

This literature review summarizes research findings related to the application of drip irrigation for smallholder farming. Focusing in particular on, review of existing knowledge on theories of adoption, adoption of agricultural technologies among smallholder farmers, theoretical framework empirical literature review of models, summary of literature review and the conceptual framework.

2.2 Theoretical Framework

There are a number of theories that explain adoption of technologies, the "top-down" and "bottom-up" models of adoption/diffusion provide a directional perspective to the process .Dichotomy theory relates to the scale of innovation efforts by distinguishing between macro-level theories and micro-level theories**.**

Citing Wahid (2007) in Taylor and Todd (1995), the problem of innovation diffusion can be approached from several levels. Some researchers have approached it from macro view or at country level and still other researchers and academic scholars have approached this issue by exploring the factors influencing adoption and usage by individuals. Macro-level theories focus on the institution and systemic change initiatives. Innovation typically involves broad aspects of curriculum and instruction might encompass a wide range of technologies and practices. Micro-level theories, on the other hand, focus on the individual adopters and a specific innovation or product rather than on large-scale change. The following are some of the theories that have been used in explaining technology adoption.

2.2.1 Diffusion of Innovations Theory

This theory traces the process by which a new idea or practice is communicated through certain channels over time among members of a social system. The model describes the factors that influence people's thoughts and actions and the process of adopting a new technology or idea. Rogers (1995), defines Diffusion of innovations (DOI) as the process “by which an innovation is communicated through certain channels over time among members of the social system”. DOI is a theory of how, why, and at what rate new ideas and technology spread through cultures, operating at the individual and firm level. DOI theory sees innovations as being communicated through certain channels over time and within a particular social system (Rogers, 1995).

Individuals are seen as possessing different degrees of willingness to adopt innovations, and thus it is generally observed that the portion of the population adopting an innovation is approximately normally distributed over time (Rogers, 1995). Breaking this normal distribution into segments leads to the segregation of individuals into the following five categories of individual innovativeness (from earliest to latest adopters): innovators, early adopters, early majority, late majority, laggards (Rogers, 1995). Critics of this model say that it is an overly simplified representation of a complex reality. Adopters often fall within different categories for different innovations: a current laggard can be an early adopter the next time around.

2.2.2 Innovation Decision Process

Rogers (2003) proposed and popularized diffusion of innovations theory. His innovation decision process theory proposes that there are five distinct stages to the process of diffusion. The stages are: First, the knowledge stage this is when the person or group begins to learn and know about a new innovation secondly, persuasion this is when the person begins to form attitudes through interactions with others. Thirdly, is the decision stage where there is a drive to seek additional information and a decision is made. Fourthly, is the implementation stage as regular use is attempted more information is sought. The confirmation stage where continued use is justified or rejected based on the evidence of benefits.

2.1.3 Rate of Adoption

The rate of adoption is defined as the relative speed with which members of a social system adopt an innovation. Rogers (1995) defines the rate of adoption as the relative speed with which an innovation is adopted by members of a social system. An innovation's rate of adoption in a system, usually measured as the number of members of the system that adopt the innovation in a given time period. It is usually measured by the length of time required for a certain percentage of the members of a social system to adopt an innovation, Sunding and Zilberman (2001).

Within the rate of adoption there is a point at which an innovation reaches its critical mass. Critical mass is the time in the adoption curve when enough individuals have adopted an innovation so that the continued adoption of the innovation is self-sustaining. The adoption process is an individual phenomenon describing the series of stages an individual undergoes from first hearing about a product to finally adopting it (Shoemaker *et al.,* 1972). On the other hand, the diffusion process signifies a group of phenomena, which suggests how an innovation spreads among consumers. Overall, the diffusion process essentially encompasses the adoption process of several individuals over time.

2.1.4 Perceived Attributes

Rogers (2003) defines several intrinsic characteristics of innovations that influence an individual's decision to adopt or reject an innovation: Relative Advantage: How improved an innovation is over the previous generation; Compatibility: The level of compatibility that an innovation has to be assimilated into an individual's life. Complexity or Simplicity: If the innovation is perceived as complicated or difficult to use, an individual is unlikely to adopt it. Trial ability: How easily an innovation may be experimented. If a user is able to test an innovation, the individual will be more likely to adopt it. Observability is the extent that an innovation is visible to others. An innovation that is more visible will drive communication among the individual's peers and personal networks, and will in turn create more positive or negative reactions.

2.1.5 Diffusion of Innovations

Diffusion of innovation is a theory profound by Everett Rogers that seeks to explain how, why, and at what rate new ideas and technology spread. Rogers argues that diffusion is the process by which an innovation is communicated over time among the participants in a social system. For Rogers (2003), adoption is a decision of full use of an innovation as the best course of action available and rejection is a decision not to adopt an innovation. Haider (2004) defines diffusion as the process in which an innovation is communicated thorough certain channels over time among the members of a social system. As expressed in this definition, innovation, communication channels, time, and social system are the four key components of the diffusion of innovations (Sahin, 2006). Therefore, this study was anchored on Diffusion of Innovations Theory.

2.3 Empirical Literature Review

This section presents the empirical literature of the study.

2.3.1 Technology Adoption by Smallholder Farmers

A farmer’s decision to adopt or discard a particular technology (such as drip irrigation) is influenced by a complex set of socio-economic, farm-related, and sometimes physical factors. Cao, Fengmin and Xuefeng (2008) suggested that the adoption of any new agricultural technology or approach to soil conservation is a complicated process, in which socio-economic, farm structural, institutional, and ecological variables are hypothesized to influence a farmer's decisions. Relevant socio-economic variables include education level, age, family size, and income. Cao *et al.,* (2008) hypothesized the positive influence of education level and income and the negative influence of age and family size. Other relevant variables include farm size, farmer's occupation, and access to extension services.

Haile *et al.,* (2001) examined several smallholder drip irrigation systems using simple technology such as a bucket reservoir, valves, and water distributing pipelines, which they characterized as systems designed to maintain the benefits of drip irrigation while eliminating factors that discourage smallholders from adopting drip irrigation, such as the high cost of system inputs, complicated system operation, and system maintenance requirements.

They noted that the relatively low level of investment capital needed to implement a simple drip system is a major advantage for smallholders, estimating the initial investment for a drip irrigation system as between US$ 500 and US$ 3,000 per hectare. If properly managed, the increased crop value in terms of quality, quantity, and time saving would enable the farmer to recuperate this investment quickly. Nevertheless, the low initial investment required may still be too expensive for poorer farmers, impeding adoption of the system, as most farmers would not risk their limited resources and fields. Given these initial investment costs, Haile *et al.,* (2001) proposed that the government should support the introduction of these sustainable horticultural production technologies.

While it is a disadvantage of the proposed simple system that water must be brought from a source and contained in a bucket or drum, small amounts of water can nevertheless irrigate an enormous area. On the basis that the average plant water requirement is 5 mm/day for land areas with a mean daily temperature of at least 20 °C, Haile *et al.,* (2001) found that one bucket of water could irrigate up to 100 square meters of land, and it would be feasible to expand that area by operating more buckets or drums. One problem associated with the use of buckets to feed water into drip irrigation systems is that the transport of water to elevated reservoirs is complicated and difficult, especially if performed manually; ideally, this is best accomplished using simple mechanical lifting devices that require no fuel or electricity.

2.3.2 Barriers to Adoption of Agricultural Technology

According to (Feder *et al.,* 1985:98; William, 2010), the potential barriers to the adoption of a technology such as irrigation are; Inadequate information, education and training. Further, He Cao *et al.,* (2007), underscores lack of access to credit especially when a significant expenditure is required to purchase equipment, inadequate or unreliable supply of equipment, insufficient transportation or infrastructure, Uncertainty and risk associated with information about the technology as other major barriers to adoption of a new technology. Gareth *et al.,* (2007) in a related study finding reinforced that micro parameters are crucially important to understanding agricultural technology adoption and can best be statistically assessed using micro-level data.

The same study also supports the findings that heterogeneity of asset quality is critical in the general study of technology adoption. Hochman *et al.*, (1978) in their theoretical research identified three broad classes of factors affecting irrigation technology choices; economic variables, environmental characteristics and institutional variables. One of the major contributions of the past studies of agricultural technology adoption to the general adoption literature is that they emphasize the role of heterogeneity of asset quality in the adoption process.

Heterogeneity is a crucial element of the threshold model of diffusion (Davies *et al.,* 2010), but many of the early threshold models focus exclusively on variations in wealth or related factors such as farm size. The agricultural technology problem highlights the importance of differences in physical or geographical conditions in explaining adoption behavior and points out that geographic information must be combined with economic data to predict adoption patterns.

Rahman & Hickey (2019) found that social and cultural interactions between members of households and other specialized groups in society also help in understanding local innovation. Complex social and cultural relationships and norms affect the use and ownership of resources, how farming operations are undertaken, how new ideas and technologies are perceived within the family; male-female interactions also influence innovation. At household level gender power relations effect decisions on adoption or failure to adopt, some technologies are easily promoted through women depending on the cost implications or even economic significance.

Busingye (2011) in explaining variance in technology adoption in time and space critically analyses training and visit (T&V)and the rigid ranch models as some extension methodologies that share common features; all being top-down, centre outwards, control oriented and intended to standardize and regulate behavior. The study concluded that in practice none could fit or serve local complex, diverse, dynamic and unpredictable conditions. They concluded that farmers do not think of adoption or non-adoption as scientists do, but select elements from the technological complexes to suit their constantly changing circumstances.

2.3.3 Demographic Characteristics and Adoption of Drip Irrigation Technology

Age is factor thought to affect adoption. Age is said to be a primary latent characteristic in adoption decisions. However, there is contention on the direction of the effect of age on adoption. Age was found to positively influence adoption of sorghum in Burkina Faso (Adesiina and Baidu-Forson, 2009), IPM on peanuts in Georgia (McNamara, Wetzstein and Douce, 2011) and chemical control of rice stink bug in Texas (Kongola, 2018). The effect is thought to stem from accumulated knowledge and experience of farming systems obtained from years of observation and experimenting with various technologies.

In addition, since adoption pay-offs occur over a long period of time, while costs occur in the earlier phases, age of the farmer can have a profound effect on technology adoption. However, age has also been found to be either negatively correlated with adoption, or not significant in farmers' adoption decisions. In studies on adoption of land conservation practices in Nigeria, rice in Guinea (Adesiina and Baidu-Forson, 2005), Hybrid Cocoa in Ghana (Boahene, Snijders and Folmer, 2009), age was either not significant or was negatively related to adoption. However, in contrast Green and Ng'ong'ola, (1993), Nguluu*et al*., (2016) found that other farmers do not adopt fertilizer use because they believe their farms are still fertile.

Older farmers, perhaps because of investing several years in a particular practice, may not want to jeopardize it by trying out a completely new method. In addition, farmers' perception that technology development and the subsequent benefits, require a lot of time to realize, can reduce their interest in the new technology because of farmers' advanced age, and the possibility of not living long enough to enjoy it (Caswell *et al*., 2011; Khanna, 2011). Furthermore, elderly farmers often have different goals other than income maximization, in which case, they will not be expected to adopt an income-enhancing technology. As a matter of fact, it is expected that the old that do adopt a technology do so at a slow pace because of their tendency to adapt less swiftly to a new phenomenon (Christensen *et al.,* 2018).

Studies in some areas have shown that smallholder farmers do not adopt all components of "packaged" technologies (Nguluu*et al*., 2006). When exposed to innovations, smallholder farmers only take those components that they perceive as useful and economically within their reach (Nguluu*et al*., 2012). Those that require a substantial cash outlay are not taken up easily (Ockwell*et al.*, 2010). There are also technologies that do not require high investment costs and still exhibit low adoption. Rukandema (2004) and Muhammad and Parton (2012) have described other socio-economic factors such as farmers' innovativeness, age, off-farm income, risk and uncertainty that may result in low technology uptake. Lack of awareness of improved practices is another reason, particularly in remote areas (Nguluu *et al*., 2014).

Studies that have sought to establish the effect of education on adoption in most cases relate it to years of formal schooling (Christensen *et al.,* 2018), Feder and Slade, 2008). Generally, education is thought to create a favorable mental attitude for the acceptance of new practices especially of information-intensive and management-intensive practices (Waller *et al*., 2008; Caswell *et al*., 2011). IPM is frequently stated to be a complex technology (Pimentel, 2010; Boahene, Snijders and Folmer, 2009). What is more, adoption literature (Rogers 2003) indicates that technology complexity has a negative effect on adoption.

Education is thought to reduce the amount of complexity perceived in a technology thereby increasing a technology's adoption. According to Ehler and Bottrell (2000), one of the hindrances to widespread adoption of IPM as an alternative method to chemical control is that it requires greater ecological understanding of the production system. For IPM, the relevance of education comes to play in a number of ways. First, effective IPM requires regular field monitoring of pests conditions to identify the critical periods for application of a pesticide or other control measures (Haider& Kreps, 2004).). Farmers' knowledge of insect life cycles is also crucial when precision is required about the best stage of the life cycle of a particular control strategy. In addition, knowledge of the possible dangers from improper use of particular practices may direct farmers to the safest application procedure regarding a given control strategy especially where chemicals are involved.

In recent studies reviewed, including Daku (2012) and Doss and Morris (2011), education positively affected IPM adoption. A study on IPM practices on potatoes identified level of education as one of the major factors that positively affected the observed level of IPM practices with Ohio potato growers (Waller et al, 2008). However, in adoption of IPM insect sweep nets in Texas, higher education was negatively related to adoption

Gender issues in agricultural production and technology adoption have been investigated for a long time. Most show mixed evidence regarding the different roles men and women play in technology adoption. In the most recent studies, Doss and Morris (2011) in their study on factors influencing improved maize technology adoption in Ghana and Akudugu, Guo&Dadzie (2012) (2010) studying coffee production in Papua New Guinea show insignificant effects of gender on adoption. The latter study notes "effort in improving women's working skills does not appear warranted as their technical efficiency is estimated to be equivalent to that of men. Since adoption of a practice is guided by the utility expected from it, the effort put into adopting it is reflective of this anticipated utility. It might then be expected that the relative roles women and men play in both 'effort' and 'adoption' are similar, hence suggesting that males and females adopt practices equally.

2.3.4 Availability of Agricultural Extension Services and the Adoption of Agricultural Technology

Additional constraints inhibiting increased fertilizer use among smallholders include lack of knowledge and ability to differentiate between various nutrient sources; and lack of understanding of cost-effective methods of soil fertility management (Muzari, Gatsi & Muvhunzi, 2012)). It has also been found that income from off-farm sources is important in the financing of purchased farm inputs (e.g. seeds, fertilizers, labor) (Muzari, Gatsi & Muvhunzi, 2012)). In addition, cash proceeds from crop sales, and income obtained from the sale of livestock and livestock products, also provide cash for the purchase of inputs in crop farming (Muzari, Gatsi & Muvhunzi, 2012). Higher levels of income from each of the above sources will lead to higher rates of adoption of yield-raising technology. Labor bottlenecks, resulting from higher labor requirements that new technologies often introduce, and seasonal peaks that may overlap with other agricultural activities, are important constraints to technology adoption.

Acquisition of information about a new technology demystifies it and makes it more available to farmers. Information reduces the uncertainty about a technology's performance hence may change individual's assessment from purely subjective to objective over time (Caswell *et al.*, 2011). Exposure to information about new technologies as such significantly affects farmers' choices about it. Feder and Slade (2004) indicate how, provided a particular technology, increased information induces its adoption. However, in the case where experience within the general population about a specific technology is limited, more information induces negative attitudes towards its adoption, probably because more information exposes an even bigger information vacuum hence increasing the risk associated with it.

A good example is the adoption of recombinant bovine Somatotropin Technology in dairy production (Mc Guirk, Preston and Jones, 1992; Klotz, Saha and Butler, 1995). Information is acquired through informal sources like the media, extension personnel, visits, meetings, and farm organizations and through formal education. It is important that this information be reliable, consistent and accurate. Thus, the right mix of information properties for a particular technology is needed for effectiveness in its impact on adoption. Good extension programs and contacts with producers are a key aspect in technology dissemination and adoption. A recent publication stated that “a new technology is only as good as the mechanism of its dissemination” to farmers (IFPRI, 2005). Most studies analyzing this variable in the context of agricultural technology show its strong positive influence on adoption. In fact, Yaron*et al.,* (2012) show that its influence can counter balance the negative effect of lack of years of formal education in the overall decision to adopt some technologies. A wide range of economic, social, physical, technical and institutional aspects of farming influence the adoption of agricultural production technologies. In a review of adoption of agro forestry technologies, Pattanayak*et al.,* (2002) established that there were five basic categories of determinants of adoption. These were farmer preferences, resource endowments, market incentives, biophysical factors and risk and uncertainty. Farmer preferences include risk tolerance, conservation attitude and intra-household homogeneity. But since these are difficult to model, proxies such as age, gender, education and social status are used instead. Resource endowments include assets which a household has such as land, labour, livestock and earnings.

Several authors identified a positive impact of the educational level of the household head on irrigation adoption (Barse*et al.,* 2010; Vaezi and Daran, 2012; Shahzadi, 2013; Singh *et al.*, 2015). Barse*et al.*, (2010) found that the high level of education of orange producers in India influenced positively the adoption of drip irrigation.

According to Vaezi and Daran (2012) and Shahzadi (2013), farmers with higher educational levels in Iran are more likely to adopt pressurized irrigation systems compared with producers with lower educational levels. Singh *et al.*, (2015) identified that as the level of education increases among Indian farmers, the likelihood of adoption of micro irrigation systems increases too.

The use of management tools in the production system is strongly related with the educational level of the producers. This implies that the greater the educational level of the producer the greater his ability to use managerial tools. Managerial skills are required for proper utilization of irrigation systems in order to obtain the incremental yield increases crucial to achieve acceptable returns on this investment (Gashu, Demment & Stoecker, 2019). Therefore, this factor can positively influence the adoption of irrigation.

The experience of the producer in the agriculture activity also influences irrigation adoption. Kumar (2012) identified that the experience in farming (proxied by the age of the producer) have a positive impact on drip irrigation adoption in India. Experience improves the awareness concerning the positive effects generated by the adoption and encourages the decision towards adoption.

However, according to Kiruthika (2014) the years of experience of sugarcane producers in India have a negative impact on drip irrigation adoption. Younger producers are more likely to be less risk averse than older producers and hence more likely to became adopters.

Joshi (2004) found positive and significant correlation between education of the farmers and their adoption level. He also reported positive and significant correlation between scientific orientation and adoption level. Gupta *et al.*, (2010) revealed that there was significant improvement in yield, quality, water and fertilizer use efficiencies of capsicum under drip irrigation and fertigation. However, the combined effect of drip irrigation and fertigation was found superior than their individual effects.

Kumar (2012) found that drip method of irrigation is found to have a significant impact on resources saving, cost of cultivation, yield of crops and farm profitability. The adoption of drip irrigation is significantly influenced by experience, farm size, proportion of wider spaced crops and participation in non-farm income activities. The policies should focus on promotion of drip irrigation in those regions where scarcity of water and labour is severe and where shift towards wider-spaced crops is taking place.

Bahuguna (1996) stated that by drip system of irrigation, 95 percent of the irrigation water can be used efficiently and the production may be increased by 30-50 percent. The above facts show the importance of drip irrigation technology.

A comprehensive adoption study by Feder *et al.*, (2005) and Feder and Umali (2003) showed that farm size, risk, human capital, and labour availability, access to credit and land tenure systems were important factors. However, studies by Besely and Case (2012b) and Foster and Rosenzweig (2005) using panel data showed that learning from own experience and neighbor’s experiences were important factors in determining adoption.

Adoption studies in Europe, Asia and Africa have identified farm and technology specified factors, institutional, policy variables and environmental factors to explain the patterns and level of adoption. For example, Oladele (2005) highlights that some studies have shown strong and positive correlation between farming size and adoption while others have shown a positive and significant association between age, farming experience, training received, social-economic status, economic motivation, innovativeness, information source and adoption. Other studies have however shown household size not significantly related to adoption.

There exist vast literatures on factors that determine agricultural technology adoption. According to (Loevinsohn *et al.,* (2013), farmers' decisions about whether and how to adopt new technology are conditioned by the dynamic interaction between characteristics of the technology itself and the array of conditions and circumstances.

Diffusion itself results from a series of individual decisions to begin using the new technology, decisions which are often the result of a comparison of the uncertain benefits of the new invention with the uncertain costs of adopting it (Hall and Khan, 2002). An understanding of the factors influencing this choice is essential both for economists studying the determinants of growth and for the generators and disseminators of such technologies (Hall and Khan, 2002).

Traditionally, economic analysis of technology adoption has sought to explain adoption behavior in relation to personal characteristics and endowments, imperfect information, risk, uncertainty, institutional constraints, input availability, and infrastructure (Feder *et al.,* 1985; Koppel 1994; Foster &Rosenzweig 1996; Kohl and Singh 1997; Rogers, 2003 and Uaiene, 2009). A more recent strand of literature has included social networks and learning in the categories of factors determining adoption of technology (Uaiene, 2009). Some studies classify these factors into different categories. For example, Akudugu *et al*., (2012) grouped the determinant of agricultural technology adoption into three categories namely; economic, social and institutional factors.

Kebede *et al.,* (2010), as cited by Lavison (2013) broadly categorized the factors that influence adoption of technologies into social, economic and physical categories. Although there are many categories for grouping determinants of technology adoption, there is no clear distinguishing feature between variables in each category. Categorization is done to suit the current technology being investigated, the location, and the researcher's preference, or even to suit client needs (Bonabana-Wabbi, 2002). For instance, the level of education of a farmer has been classified as a human capital by some researchers while others classifies it as a household specific factor.

According to Just and Zilberman (1983), there are various factors that influence the adoption of any technology. Technology may require some costs that are associated with new equipment's and investments, learning time, locating and developing markets and training labour. This view is supported by Bonabana- Wabbi (2002) adding that for farmers to adopt a technology, they must see an advantage or expect to obtain greater utility in adopting it.

From the study, it is argued that without a significant difference in outcomes between two options and in the returns from alternative and conventional practices, it is less likely that farmers, especially smallholder farmers will adopt a new practice. Since adoption of a practice is guided by the utility expected from it, the effort put into adopting is reflective of its anticipated utility. Moreover, there is no standard way of classifying factors influencing adoption and classification cannot be uniform (Bonabana-Wabbi, 2002).

This is because the factors influencing adoption may be a complex set of interactions and factors like the institution (administration), the potential/targeted adopter (the farmer) or the general setting in which the technology is introduced act either as barriers or enhancers of adoption. Several factors have been found to influence adoption. A study by Bonabana-Wabbi (2002) used multivariate Logit analysis to identify factors and their relative importance in explaining adoption of eight

Integrated Pest Management (IPM) agricultural technologies in Kumi District, Eastern Uganda.

The study results indicated that size of household labour force had negative influence on IPM adoption but positive influence on growing improved IPM. For the gender variable, the study indicated that males were more likely to adopt IPM than females while experience positively influenced timely planting of cowpeas. The study argued that, farmers with accumulated farming experience may have acquired encouraging returns from the practice and thus continue with it anticipating continued benefits. Farm size and level of education did not show any significance with IPM adoption. Although the study analyzed quite a number of factors, access to market, infrastructure and land tenure were left out in the study.

Nchinda, Hadley, Villano& Morales, 2020) used Tobit regression method as the main analytical tool in a study of factors influencing adoption and intensity of yam seedling technology in Cameroon. Farm size was not a significant determinant of adoption in their study. However, hired labour and membership to farmers' organizations positively and significantly influenced the adoption and intensity of yam minisett technology (is a way to obtain healthy planting materials in commercial quantities) in areas covered. They also showed that age had significant influence with farmers less than forty-one years of age being found to positively influence yam adoption and its intensity.

Another study by Adeogun *et al.*, (2009), aimed at estimating and explaining the parameters of the adoption process of Hybrid Clarias"Heteroclarias" by fish farmers in Lagos State Nigeria, showed age, farming experience and farm size to be statistically significant in explaining hybrid catfish adoption. However, their Logit model results showed that education, contact with extension agents, access to seed and market distance were significant variables that influence fish farmers on hybrid catfish adoption and use decisions.

In a study by Engindeniz (2007) on comparative economic analysis between contract-based and non-contracted farmers, a binary Logit model was estimated to determine the factors which make farmers prefer to grow tomato on contract-based. Some of the independent variables of the regression included age of farmers, education level, and tomato growing experience, market conditions and cooperative membership of farmers. The results pointed out that important factors affecting the profitability of tomato growing were market conditions and cooperative membership of farmers.

The study concluded that contract-based agriculture can put farmers in a position to achieve greater access to credit, inputs (in particular, new technologies) and the market, relative to their peers who are not operating under contractual arrangements. Jans and Fernandez-Cornejo (2001) in a study on the economics of tomato organic growing in the United States used the probit model to determine factors influencing adoption. Their findings were that education level; contract farming and crop price were significant and positively influenced adoption. The price was very significant and the researchers attributed this to the fact that adoption was significantly related to price premiums. In the same study, farm size was found to be negatively significant while age and off-farm employment were not significant.

Oyekale and Idjesa (2009) showed that education, access to credit, access to farm inputs and farming experience significantly and positively influenced adoption of improved maize seeds in the River State Nigeria. The study argued that, access to credit permits farmers to invest in a new technology or acquire related inputs such as, labour and fertilizer.

In the same study, absence of visits from extension services highly influenced the adoption negatively. On the contrary, contacts and access to extension services had positive and significant influence on adoption and intensity of technology according to a similar study of adoption of improved maize seeds in Tanzania (Nkonya *et al*., 1997). In a nut shell, adoption of a technology may be dependent on a number of factors which are dynamic both in terms of geographic setting and in time (Bonabana–Wabbi, 2002). Logit regression was adopted since the model is mathematically simpler in estimation than the probit model and the effects of the independent variables area analyzed for each outcome as opposed to ordered Probit model where only one coefficient is estimated for all the outcomes (Aldrich and Nelson, 1984). Drip irrigation requires higher capital to establish, run and maintain for it to serve its intended purpose efficiently (Clifton, 2004).

2.4 Review of Binary Models

Probit, Tobit and logit models have been used in many studies to determine significance of the factors influencing adoption. These are regression models used when the dependent variable is categorical in the sense that their responses consists of a set of categories. Both the Probit and Logit models are probabilistic dichotomous choice qualitative models that assume a normal cumulative distribution function and a logistic distribution of the dependent variable, respectively. They are evaluated as a linear function of explanatory variables with similar results, and the use of either model is thus discretionary.

2.4.1 Probit Model

Probit model is a logistic distribution bound between 0 and 1. According to Montgomery *et al*., (2001), Probit models lack flexibility in that they do not easily incorporate more than one prediction variable unlike Logit models. For this reason, probit models are widely used in limited dependent variable models. Shekya and

Flinn (1958) have recommended probit for functional with limited dependent variables that are continuous between 0 and 1.

The model was specified by Theil, 1979) and Maddala, 1983) as shown in equation 2.1;

$$In(E[Y \mid X_i]) = \beta + X_i\beta + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.1$$

Where β are estimated coefficients and X_i are independent variables such as farmer and farm's characteristics ε_i are stochastic error terms. The probit model uses a logistic curve to transform binary responses into probabilities within the 0-1 interval. This postulates that the probability of a farmer (P) adopting drip irrigation technology is a function of some characteristics X_i. These characteristics may be social, economic or institutional.

The model is used to examine relationship between adoption and determinants of adoption which involve a mixed set of qualitative and quantitative analysis. Qualitative models have been extensively used in adoption studies although they have been criticized for their inability to account for partial adoption (Feder *et al.*, 1985). Alternative specifications of qualitative choice models include the linear probability models and logit models. These are the two most frequently used applications in explaining the socio-economic phenomena, especially for analyzing relationship between dependent discrete variables (adoption) and explanatory variables (Polson *et al.*, 1992). Both the probit and logit models yield similar parameter estimates and it's difficult to distinguish them statistically.

Of the two models, the bivariate probit model is easier to estimate and simpler to interpret (Abebaw and Belay, 2001). Quite a large number of studies have investigated the influence of various socio-economic, cultural and political factors on the willingness of farmers to use new knowledge. In many of the adoption behavior, the dependent variable is constrained to lie between 0 and 1 and the model to be used would be the exponential functions while univariate and multivariate logit and probit models including their modified forms have been extensively used to study the adoption behavior of farmers and consumers.

Shekya and Flinn (1958) have recommended probit for functional with limited dependent variables that are continuous between 0 and 1 and logit models for discrete dependent variables. In the study the responses that was recorded would be discrete (mutually exclusive and exhaustive) and therefore bivariate probit model will be used to analyze the adoption behavior of smallholder horticultural farmers to drip irrigation technology. To measure an outcome of such discrete output, a variety of multivariate statistical techniques can be used to predict a binary dependent variable from a set of independent variables. Multiple regression and Discriminant analysis are two techniques for this purpose. However, these techniques pose difficulties when dependent variable has only two values; 1 if the event occurs and 0 if it does not.

2.4.2 Tobit Model

The Tobit is a censored model where the dependent variable assumes the value zero to one, with positive probability. The model is therefore useful for adoption and intensity of technology analysis, although some researchers combine Tobit with Probit or Logit in determining adoption behavior and intensity based on a two stage decision argument (Nchinda*et al*., 2010). Tobit model is useful when some observed values are 0 while others are not zero for instance expenditure studies.

2.4.3 Logit Model

Logit model is a logistic distribution bound between 0 and 1. The model was specified by Amemiya (1984), Theil, (1979) and Maddala, (1983) as shown that;

$$In(E[Y \mid X_i]) = \beta + X_i\beta + \varepsilon_i \text{ ……………………………………………………..2.2}$$

Where β are estimated coefficients and X_i are independent variables such as farmer and farm's characteristics ε_i are stochastic error terms.

2.5 Conceptual Framework

The conceptual framework shows the influence of independent variables on dependent variable. A farmer's decision to adopt drip irrigation will be influenced by social, economic and institutional factors. The drip farmer production depends on farmer's social characteristics including, gender, age, education and experience in use of drip irrigation. Economic factors such as farm income, farm size, and land tenure influence adoption of drip irrigation technology by the farmer. Institutional factors included: access credit availability of extension service and frequency of extension services. Given a farmer's socio-economic characteristics and institutional factors, the farmer had a choice, to adopt the drip irrigation technology for crop production. Figure 2.1 indicates that small scale farmers' adoption of drip irrigation technology is likely to be influenced by socio-economic and institutional characteristics of the farmers. The relationship between the independent and dependent variables is as summarized in figure 2.1

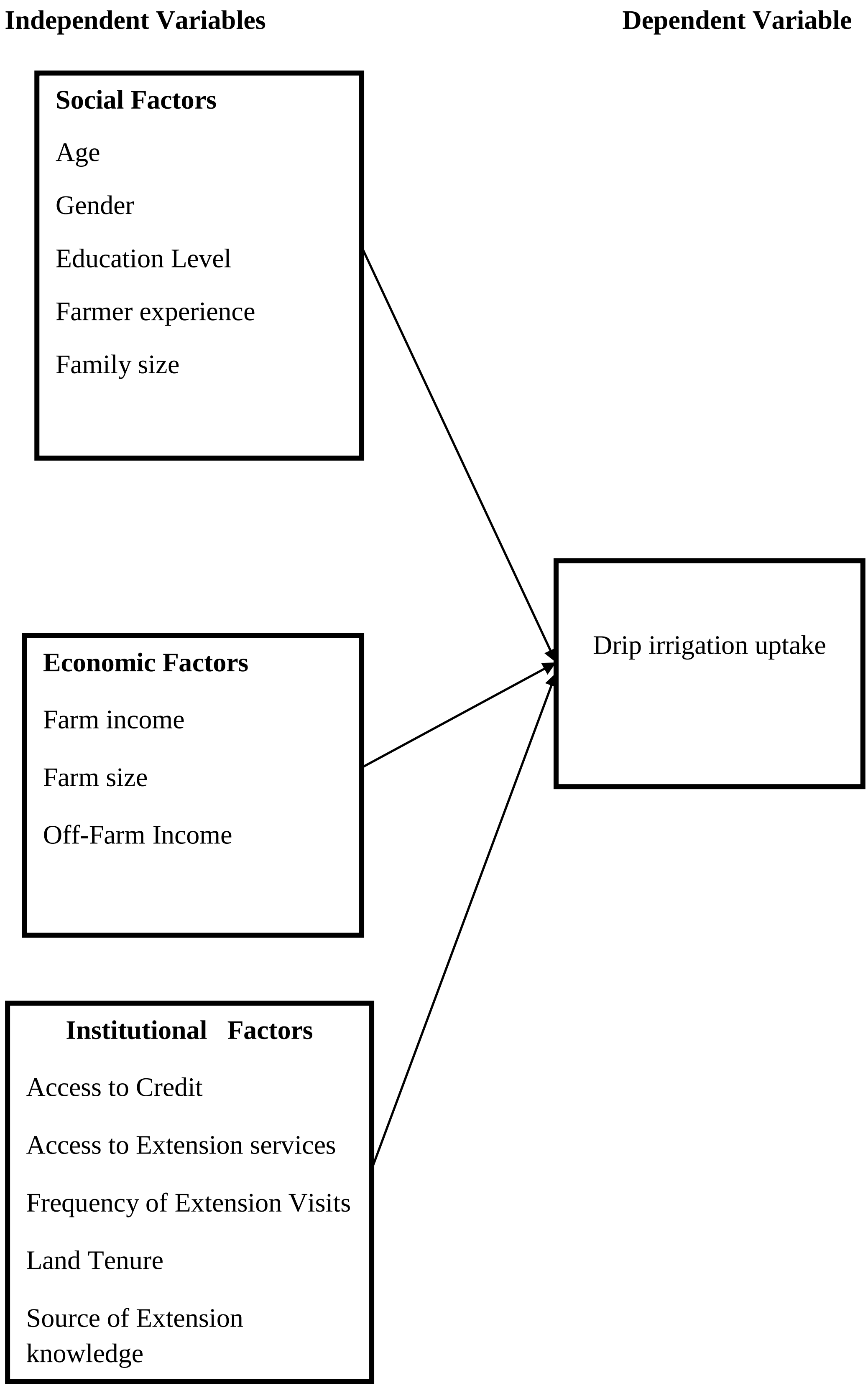


Figure 2. 1: Conceptual Framework

Source: Author's own Conceptualization, 2017

CHAPTER THREE: RESEARCH METHODOLOGY

3.1Overview

The chapter presents the study area, research design, data type and sources, target population, sample size, sampling procedure, data collection instrument, data analysis and model specification.

3.2Study Area

The study was done in Nakuru County that comprises of eleven Sub counties namely: Subukia, Rongai, Molo, Njoro, Bahati, Naivasha, Kuresoi North, Kuresoi South, Gilgil, Nakuru East and Nakuru West. However, for this study Subukia Sub County was purposively selected. This is because there have been tremendous efforts to promote drip irrigation to increase food security in this region.

3.2.1 Subukia Sub County

Subukia Sub county was curved from the Sub counties of Rongai and Nakuru North (now Bahati) is one of the eleven Sub counties in the Nakuru county. It lies within the Great Rift Valley and borders three other Sub counties namely, Rongai to the west, Laikipia to the north, Nakuru North to the south and south west. The Sub County covers an area of 390.8 Km^2. The Sub County has three wards namely Subukia, Kabazi, and Waseges Ward. It has a total of 31,600 ha of agricultural land and 23,900 Ha is cultivated.

The Sub County has a projected population of about 120,000 persons. There are 23,600 households and 21,500 farm families, (MoALF, 2016). The Sub County receives a bimodal rainfall. The long rains normally start from mid-March to August; the short rains are received in the months of September –December. The annual rainfall ranges from 700mm- 1400mm.Main Agricultural Economic Activities are: Farming which includes, Maize- beans intercrop, Vegetables, tea, coffee, Livestock keeping. Trade which involve: - Sale of agricultural produce- Cereals, Horticultural produce and livestock. The poverty level is 46 per cent (MoALF, 2016).

Promotion of irrigation technology to supplement rain fed agriculture has been undertaken by both the government and Non-governmental organizations. The site was selected because there has been a tremendous effort to promote irrigation to increase food security. The researcher has wide experience working in the area and which made collection of needed information easy and reliable. The study area was also convenient, close and easy to access hence allowing more time to collect data at a minimal cost.

3.3 Research Design

The research design that was used for this study was a census study. This is because it allowed the researcher to collect the data from all members of the scheme. This was possible because the population of scheme was 277 members which was within a manageable size. The data were collected through the use of questionnaire which was a set of questions asked to an individual.

The methodology that was employed in the study was quantitative, involving the collection of data using a structured questionnaire. A quantitative survey allows for the use of econometric models to determine the influence of different factors on adoption of drip irrigation technology by small scale farmers in Subukia Nakuru County.

Adopters and non-adopters' households were used as units of study because it is in the households that major decisions relating to production are made. Social, economic and institutional factors on adoption of drip irrigation were investigated. Each household was visited once and the responses were recorded on the questionnaire.

3.4: Data Types and Sources

3.4.1 Primary Data and Sources

Primary data was obtained from the households' head including information on age (in years), gender (male or female), education level, farmer experience (in years), family size, crop income (in Kshs), farm size, off-farm income (in KSh.), land tenure (either freehold, communal or leased) access to credit (in Kshs) and access to extension services and frequency of extension visits and source of extension knowledge in Subukia Sub County.

3.5.2 Secondary Data and Sources

Secondary data was used where historical information was required. Secondary information was obtained from the Ministry of Agriculture, Research Institutions Kenya National Bureau of Statistics (KNBS) publications journals, theses, and other government institutions. Government publications such as national and County, Sub County development plans, and annual reports among others were also used.

3.6 Target Population

The target populations for the study were the smallholder horticultural farmers in Lari Wendani irrigation scheme, Subukia Sub County, comprising of both adopters and non-adopters. The number of households was 277, (MoALF, 2016).Since the total numbers of farmers in the scheme were 277, a census study was used. Therefore, the total number of respondents in this study was 277 farmers. There are 7 schemes in Lari Wendani irrigation scheme.

3.7RespondentsDistribution per Scheme

Census was used and as such, no sampling procedure was required. Identifying the 1st respondent used the farmers register complied by the scheme management.

Table 3. 1: Distribution of Respondents Per Scheme

scheme 1	scheme 2	scheme 3	scheme 4	scheme 5	scheme 6	scheme 7	Total
29	28	36	27	52	39	66	277

Source: **Author's Own Computation (2017)**

3.8 Data Collection Instrument

A structured questionnaire was used to collect data from the surveyed farmers. Quantitative data was collected from the study area; pretest of the data collection tool was done in Arash location to establish reliability of the research instrument.

3.9 Data Analysis

Data was analyzed using a combination of descriptive and inferential statistics.

3.9.1 Descriptive Statistics

Descriptive statistics concerns the summarization of data (Saunders, Milyavskaya, Etz, Randles, Inzlicht & Vazire, 2018). Descriptive statistics were used to summarize and describe data from the surveyed households. This usually entails calculating numbers from the data, called descriptive measures, such as percentages, sums, averages, standard deviation, minimum and maximum values (Saunders *et al.*, 2018). The technique was useful in analyzing all the quantitative data. In this case, cross tabulation, frequency tables and descriptive statistics such as mean, standard deviation of study variables were calculated. Minimum and maximum values of each variable were identified. Descriptive statistics are useful as they represent pictorial view of the data.

3.9.2 Inferential Statistics

Inferential statistics does more than descriptive statistics. There is an inference associated with the data set, a conclusion drawn about the population from which the data originated (Saunders *et al.,* 2018). Inferential statistics such as correlation and regression analysis were used as to ensure efficient inferences are made to the larger population. Inferential statistics was used to infer sample results to the general population. In this study logit model was used.

3.10 Choice of Econometric Model

There is no articulated model that provides a conceptual framework to determine the factors that influence drip irrigation adoption decision. However, studies have been carried out to relate farmers' adoption of new technologies to various socio economic factors (Anderson & Feder, 2004). Based on these studies, a conceptual model was developed to explain the effects of socio- economic factors on the adoption of drip irrigation technology.

In adoption studies, responses to a question such as whether farmers adopt a given technology could be yes or no, is a typical case of dichotomous variable. The model that is suggested for such binary dependent variable is the linear probability model. However, the use of this model is not appropriate to evaluate the effect of explanatory variables due to well-recognized econometric problems associated with this model.

The inadequacy of the linear probability model suggest that a non-linear specification may be more appropriate and the candidate for this will be S- shaped curve bound in the interval of 0 and 1 (Pindyck and Rubinfeld, 1981). The author suggested the S - shaped curves satisfying the probability model as those represented the cumulative logistic function (logit) and cumulative normal distribution function (probit).

For this study the logistic distribution function (logit) model was selected. The logistic function was used because it represented a close approximation to the cumulative normal distribution and is simpler to work with. Hosmer and Lemeshow (1989) has pointed out that the logistic distribution has advantages over the others in the analysis of dichotomous dependent variable. The logistic distribution is extremely flexible, and lends itself to a meaningful interpretation.

3.9.1Specification of the Logit Model

According to Pindyck and Rubinfeld, (1991) sited by Nzomoi *et al.*, (2007), this model is based on the cumulative logistic probability function and its specification takes the following form:

$$p(i) = F(Z_i) = F(a + bX_i) = \frac{1}{(1+e^{-zi})} = \frac{1}{\left(1+e^{-(a+bX_i)}\right)} \text{..............................} \quad 3.1$$

Where, in this notation ***'e'*** represents the base of natural logarithms which is approximated at 2.718. Pi is the probability that an individual will make a certain choice, in this case whether to adopt drip irrigation technology or not. In estimating equation (1) stated above, we multiply both sides by $(1+e^{-z})p_i = 1$ so that dividing by p_i and then

Subtracting 1 yield: $e^{-z_i} = \frac{1}{p_i} - 1 = (1-p_i)/p_i$ 3.2

However since $e^{-z} = 1/e^{z}$ then $e^{z_i} = p_i/(1-p_i)$ so that by taking the natural logarithm on both sides of the equation we obtain $z_i = \log(p_i/(1-p_i))$ or from equation (1) presented above, we have:

$$Log\ \frac{p_i}{1-p_i} = Z_i = a + bX_i \qquad 3.3$$

Where $Log\ \frac{p_i}{1-p_i}$ = the log of the odds that a certain decision will be made.

a = the constant of the equation

b = the coefficient of the predictor variables

3.10 Description and Measurement of Variables

Table 3. 2: Description, Measurement and Expected Signs of Variables

Variable	Description	Measurement	Expected Sign
Y1	Adoption	0- Not adopted 1-Adopted	
X_1	Age of household head	Number of years	-/+
X_2	Gender	Male or female 0-Female 1 -Male	-/+
X_3	Level of education	Subdivisions of formal learning, typically covering early childhood education, primary education, secondary education and tertiary education	+
X_4	Farmer experience	Number of years in farming .	+
X_5	Farm income	Household income from drip irrigation in Kenyan shillings	+
X_6	Farm size	Total land size of the household in hectares	+
X_7	Land tenure	Type of land ownership 1-Owned; 2-Communal 3-Rented/leased	+
X_8	Access to credit	Access to credit financial services 1-Yes;0-No	+
X_9	Extension services	Access to extension service 1-Yes; 0-No	+
X_{10}	Frequency of extension visits	Number of times visited per year	+
X_{11}	Family size	Number of members in Household	+/-
X_{12}	Off-farm income	Household income from other sources	+

Source: **Author's own Computation, 2017**

For this study description and measurement of the variables has been illustrated in the Table 3.2 together with the expected sign.

3.11 Diagnostic Tests

Logit regression analysis was used to test for heteroscedasticity to ensure that there was constant variance.

3.11.1 Heteroscedasticity Test

The variance of linear regression model should be constant for the linear regression model to hold. If the error terms do not have the constant variance, they are heteroscedastic. Breusch-Pagan and Cook-Weisberg test was used to test for heteroscedasticity. It has the null hypothesisH_0: constant variance. The Lagrange Multiplier test yields the following test statistic;

$$LM = \left(\frac{\partial L}{\partial \theta}\right)^T \left(E\left[\frac{\partial^2 L}{\partial \theta \partial \theta^1}\right]\right)^{-1} \left(\frac{\partial L}{\partial \theta}\right) \quad 3.4$$

3.11.2 Test for Multicollinearity

Variance inflation factor (VIF) was applied to check for Multicollinearity in logit regression analysis. VIF measures how a variance has increased the estimate of the slope High VIFs reflects an increase in the variances of estimated regression coefficients due to collinearity among predictor variables. VIF test for Multicollinearity is denoted as;

$$VIF = \frac{1}{1-R^2} \quad 3.5$$

3.12 Ethical Considerations

In the course of this study several research were considered. First, theresearcher made sure that participation of the sampled respondents was voluntary by obtaining informed consent from the respondents. Secondly, anonymity and confidentiality of information was assured and the participants' identification were kept confidential. All the respondents' information and identity were kept confidential. Prospective respondents were informed of the purpose of the study. In this research, respondents were informed about the nature and the purpose of the study and the information gathered was used only for the purposes of this study.

3.13 Scope and Limitation of the Study

The study covered only Subukia Sub County. This was mainly due to limitation of resources in terms of time and funds required to undertake the study on a larger scale. The study targeted small-scale farmers in the area, and sample size was 277 households. The key issues in this study were social, economic and institutional characteristics of smallholder drip irrigation farmers. Structured questionnaire was used to collect data. To deal with the problem of illiteracy of respondents, there was training and close supervision of enumerators so as to eliminate distortion of information and improve on the quality and reliability of data that were collected.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 Overview

This section presents results and discussions of the study. Descriptive statistics of the variables are presented in the first part.

4.2 Demographic Characteristics of the Surveyed Households

This section presents the demographic characteristics of the households surveyed.

4.2.1 Age Distribution of the Surveyed households

Table 4.1 presents the age distribution of the surveyed households. Results showed that the average age was 50 years. This implied that majority of the surveyed households were within the most active age in farming activities. These findings concurred with the previous findings of Ongiyo (2016) who found that most of the sample farmers were within the most active age in terms of economic activities.

Table 4. 1: Age Distribution of the Surveyed Households

Variable	Obs.	Mean	Std. Dev	Minimum	Maximum
Age of the Household Head	277	50.0794	13.0681	18	79

Source: Authors Survey Data, 2017

4.2.2 Gender Distribution of the Surveyed households

Table 4.2 reports the gender distribution of the surveyed households. Results depicts that majority of the surveyed households were male 208 (75.09 per cent). This indicated that most of the surveyed households were male headed implying that most household decisions concerning farming activities were made by male. This is because males are more exposed to information than female concerning new innovations. Dey (1981) and Ongiyo (2019) noted that male farmers are likely to have more access to inputs, capital and information through farmers' networks and contacts with extension agents than female farmers.

Table 4. 2: Gender Distribution of the Surveyed households

Gender	Frequency	Percent	Cum. Per cent
Female (Coded 0)	69	24.91	24.91
Male (Coded 1)	208	75.09	100
Total	277	100	100

Source: Author's Survey Data, 2017

4.2.3 Household Sizes of the Surveyed households

Table 4.3 gives the household sizes of the surveyed households. Table 4.3 shows that the average number of persons living in one household among the surveyed farmers was 7 with standard deviation of 2.5. The minimum number in the surveyed households was one (1) person while the maximum were 15 people. This was an indication that there was enough provision of labor for drip irrigation because most of the households in developing countries use family members as source of labour for farming activities.

Table4. 3: Household Sizes of the Surveyed households

Variable	Obs.	Mean	Std. Dev	Minimum	Maximum
Household Size	277	6.7	2.5	1	15

Source: Authors Survey Data(2017)

4.2.4 Education Level of the Surveyed Households

The results of education level of the surveyed households are depicted in Table 4.4. Result showed that majority of the surveyed household had primary education (137 that represented 49.46 per cent. This was followed closely by secondary level of education (121 farmers that represented 43.68 per cent. A paltry 3 (1.08%) farmers had no education at all. These results are consistent with the findings of Anderson & Feder (2004) who reported that majority of the respondents were under medium level of education.

Education represents quality of human capital since it is thought to be largely responsible for improving access to new information on new technologies and the general economic welfare of the people (Schultz, 1981; and Ongiyo (2019). 2014). This is an indication that on average, the farmers were enlightened and hence they may be front-runners in the adoption of drip irrigation technology. Since their education may enhance their access to information and willingness to try out innovations (Schultz, 1981).

These findings are consistent with the previous findings of Siele, Tuitoek & Otieno (2015) and Anderson & Feder (2004).) who reported that majority of the respondents were under medium level of education. This is an indication that on average, the respondents were enlightened and hence they may be early adopters in the adoption of drip irrigation technology. This is because their education may enhance access to information and willingness to try out new innovations (Schultz, 1981).

Table 4. 4: Education Level of the Surveyed Households

Education Level	Frequency	Percent	Cum. Per cent
Primary	137	49.46	49.46
Secondary	121	43.68	93.14
Post-Secondary	16	5.78	98.92
None	3	1.08	100
Total	**277**	**100**	**100**

Source: Author’s Survey Data, 2017

4.3 Land Size of the Surveyed Households

Table 4.5 presents the land size of the surveyed households. Result showed that the average land holding was 2.9 acres with standard deviation of 1.9. The minimum holding was 0.25 acres while the maximum was 23.50 acres. This was an indication that majority of the surveyed households were small-scale farmers. Misra (1990) and Kannan (2002) in their respective studies in India reported that majority of the respondents had medium size (2-4 ha) of land holdings. Similarly, Ongiyo (2019) reported that most of the respondents were small-scale farmers in his study on adoption of dairy technologies in North Rift Kenya.

Table 4. 5: Land Size Distribution of the Surveyed Households

Variable	Obs.	Mean	Std. Dev	Minimum	Maximum
Land Size	277	2.9752	1.936	0.25	23.50

Source: Authors Survey Data, 2017

4.4 Land Ownership Pattern of the Surveyed Households

Table 4.6 presents the results of land ownership pattern of the surveyed households. Results indicate that majority of the sampled households owned their lands (265 farmers that represented 95.67 per cent). Twelve farmers (4.33 per cent) leased their lands while none owned land under communal system.

Table 4. 6: Land Ownership Pattern of the Surveyed Households

Land Tenure System	Frequency	Percent	Cum. Per cent
Owned	265	95.67	95.67
Leased	12	4.33	100
Communal	0	0	0
Total	277	100	100

Source: Author’s Survey Data, 2017

4.5 Adoption Level of Drip Irrigation Technology

The study sought to establish the number of farmers who used drip irrigation and the results are presented in Table 4.7. Results showed that adoption level was low because 228 farmers (82.31 per cent) did not use drip irrigation. This was an indication that the technology was expensive or farmers were not aware of the benefits of using the innovation or attitude of the farmers towards the technology was negative.

Table 4. 7: Adoption of Drip Irrigation by the Surveyed Households

Level of adoption	Frequency	Percent	Cum. Per cent
Non-Adopters	228	82.31	82.31
Adopters	49	17.69	100
Total	**277**	**100**	**100**

Source: Author's Survey Data, 2017

4.6 Type of Drip Irrigation Technology

The study also sought to establish type of irrigation technology used by surveyed households. There were three technologies; furrow, sprinkler and others. The results are reported in Table 4.8. Results in Table 4.8 showed that majority of the surveyed households 134 (48.38 per cent) used sprinkler technology while 83 (29.96 per cent) used other techniques like basins. Few of them 60 (21.66 per cent) used furrow irrigation. Farmers cited that furrow technology was expensive and results in loss of water through evaporation. This was in line with Irrigation Show (2009) who stated that furrow irrigation has high precipitation and water loss.

Table 4. 8: Type of Drip Irrigation Technology used by Surveyed Household

Type of Irrigation Technology Used	Frequency	Percent	Cum. Per cent
Furrow	60	21.66	21.66
Sprinkler	134	48.38	70.04
Others	83	29.96	100
Total	**277**	**100**	**100**

Source: Author's Survey Data, 2017

4.1.9 Experience in Farming under Drip Irrigation by the Surveyed Households

The study collected and analyzed data on how long the farmers have been practicing farming under drip irrigation. The results are presented in Table 4.9. Results indicated that on average farmers have practiced farming under irrigation for 7.5 years with standard deviation of 5.3. The minimum experience was zero (0 years) and these were the farmers who had not adopted farming under drip irrigation.

Table 4. 9: Experience in Farming under Irrigation by the Surveyed Households

	Mean	Std. Dev	Minimum	Maximum
Years in Irrigation	7.5	5.3	0	35

Source; Authors Survey Data, 2017

4.1.10 Income Earned from Drip Irrigation by the Surveyed Households

The study also collected and analyzed data on the amount of income earned from drip irrigation farming in the previous years. The results are presented in Table 4.10. Results indicated that average income from crops under drip farming was KSh. 7,152 with standard deviation of KSh. 18,571.4. The minimum income from drip farming was zero (0) showing that some farmers did not practice drip farming at all.

Table 4. 10: Income Earned from Drip Irrigation by the Surveyed Households

Variable	Mean	Std. Dev	Minimum	Maximum
Income from Drip Farming	7151.657	18571.4	0	140000

Source; Authors Survey Data, 2017

4.1.11 Off-Farm Income Earned by the Surveyed Households

The study also collected and analyzed data on the amount of off-farm income earned by the surveyed households. The results are presented in Table 4.11.

Table 4. 11: Off-Farm Income Earned by the Surveyed Households

Variable	Obs.	Mean	Std. Dev	Minimum	Maximum
Income from off- Farm	277	22690	14334	10000	59000

Source; Authors Survey Data, 2017

Results indicated that the average off-farm income was Ksh. 22690 with standard deviation of Ksh. 14334. The minimum off-farm income was Ksh. 10000, which showed that farmers practice other types of economic activities. The maximum off-farm income was Ksh. 59000.

4.1.12 Access to Extension Services by Surveyed Households

The study sought to establish whether the surveyed household accessed extension services. The results are reported in Table 4.12. Results showed that majority (92.06 per cent)of the surveyed households accessed extension services. Few, 22 (7.94 per cent)of them did not accessed extension services. This was an indication that extension services were available in the study area.

Table 4. 12: Access to Extension Services by Surveyed Households

Access to Extension Services	Frequency	Percent	Cum. Per cent
Accessed	255	92.06	92.06
Did not Access	22	7.94	100
Total	277	100	100

Source: Author's Survey Data, 2017

4.1.13 Sources of Extension Knowledge by Surveyed Households

The study sought to establish sources of the extension knowledge by the surveyed households. Results in Table 4.13 showed that majority of the surveyed households; 156 farmers (56.32 per cent) accessed extension services extension personnel (MoALF). Ninety-five farmers accessed extension knowledge from mass media while 25 of them accessed extension knowledge from other sources. This was an indication that extension personnel from MoALF were available in the study area.

Table 4. 13: Sources of Extension Knowledge by the Surveyed Households

Sources of Extension Knowledge	Frequency	Percent	Cum. Per cent
Mass Media	25	9.03	9.03
Extension Personnel –MoALF	156	56.32	65.34
Research Institutes	95	34.30	99.64
Others	1	0.36	100
Total	**277**	**100**	**100**

Source: Author's Survey Data, 2017

4.1.14 Frequency of Extension Visits of Surveyed Households

The study sought to establish the frequency of extension visits by surveyed households. The results are reported in Table 4.14. Results in Table 4.14 showed that majority (121) of the surveyed households did not receive extension services while 4 of them were visited for 10 times. This was an indication that extension personnel from MoALF were available in the study area but their contact was very minimal with the farmers. This is because in Table 4.13 farmers accessed extension services but Table 4.14 show that they did not get extension (farming) knowledge.

Table 4. 14: Frequency of Extension Visits of Surveyed Households

Frequency of Extension Visits	**Frequency**	**Percent**	**Cum. Per cent**
Zero Times	121	43.68	43.68
One Time	56	20.21	63.89
Two Times	51	18.41	82.30
Three Times	16	5.77	88.07
Four Times	10	3.61	91.68
Five Times	4	1.44	93.12
Six Times	8	2.88	96.00
Seven Times	1	0.36	96.36
Eight Times	6	2.16	98.52
Ten Times	4	1.44	100.00
Total	**277**	**100.00**	**100.00**

Source: Author's Survey, 2017

4.1.15 Access to Credit by the Surveyed Households

The study was to establish whether the surveyed households accessed credit facilities. The results of access to credit are presented in Table 4.15. Results indicated that majority (222 farmers representing 80.14 per cent)of the surveyed households did not access credit facilities. This may imply that credit facilities through banks and other financial institutions were rare facilities in the study area. Also it implies that such farmers lack collaterals to banks as security to get loan facilities.

Table 4. 15: Access to Credit Facilities the Surveyed Households

Access to Credit Facilities	Frequency	Percent	Cum. Per cent
Accessed Credit	222	80.14	80.14
Did not Access Credit	55	19.86	100
Total	277	100	100

Source: Author's Survey Data, 2017

4.1.16 Use of Loan for Drip Irrigation

The study sought to establish whether farmers who accessed credit facilities used the loan obtained for drip irrigation farming. Results showed that all the surveyed households did not use loan awarded on drip irrigation farming. This is an implication that farmers may get loan and invest in other more profitable enterprise other than drip irrigation farming.

Table 4. 16: Use of Loan Facility for Drip Irrigation of the Surveyed Households

Use of Credit on Drip Irrigation	Frequency	Percent	Cum. Per cent
Used Credit on Drip Irrigation	0	0	0
Did not Use of Credit on Drip Irrigation	277	100	100
Total	**277**	**100**	**100**

Source: Author's Survey Data, 2017

4.12 Diagnostic Checks

4.12.1 Breusch-Pagan and Cook-Weisberg Test for Heteroscedasticity

The diagnostic tests were done before testing the hypotheses. Breusch-Pagan and Cook-Weisberg Test for Heteroscedasticity was done to ensure that there was constant variance. Results of Breusch-Pagan and Cook-Weisberg test for heteroscedasticity indicate constant variance (p – value 0.17 > 0.05). The null hypothesis for this test is that the error variances are all equal, therefore this hypothesis was maintained.

4.12.2 Test for Multicollinearity

Variance inflation factor (VIF) is applied to detect for Multicollinearity in regression analysis (Murray, Nguyen, Lee, Remmenga, & Smith (2012). Models with multicollinearity have lower precision and have problems in forecasting. From the test it was found that the mean VIF was 6.45 which is less than 10 and this indicated absence of multicollinearity.

4.12 Logit Regression Results and Test of Hypotheses

The main purpose of this study was to analyze social, economic and institutional factors influencing adoption of drip irrigation technology among smallholder horticultural farmers in Subukia Sub County, Nakuru County, Kenya. The logit regression results are presented in Table 4.17.

Table 4. 17: Logit Regression Results on Adoption of Drip Irrigation

				Number of obs. 277
				LR χ^2 (13) = 192.13
				Prob > χ^2 = 0.0000
Log likelihood = -2203.4075				*Pseudo* R^2 = 0.4180
Variable	Coef.	Std. Err.	Z – Stat	Pob. > Z
Age	-0.1125	0.0267	-4.21	0.0000**
Gender	0.2243	0.1789	1.25	0.2100
Education level	0.0922	0.1062	0.87	0.3860
Farmer experience	0.5607	0.8927	6.28	0.0000**
Experience in farming	-0.0184	0.1371	-1.34	0.1800
Family size	-0.01345	0.0150	-0.90	0.3700
Farm income	-0.0819	0.0976	-0.84	0.4010
Land size (acres)	0.0581	0.0284	2.04	0.0411**
Off-Farm income	0.0254	0.0058	4.35	0.0000**
Access to credit	0.0608	0.0209	2.89	0.0040**
Access to extension services	0.0879	0.2225	3.95	0.0000**
Frequency of extension visits	0.0291	0.0048	6.00	0.0000**
Land tenure	0.0098	0.0031	3.14	0.0020**
Source of extension knowledge	2.5914	0.4122	6.29	0.0000**
Constant	-0.2223	0.1244	-1.79	0.0740

Note: ** indicates the variables that were significant 5% level of significance
Source: Author's Survey Data, 2017

The logit regression results on use of drip irrigation reported in Table 4.17. With 0 - 4 iterations, Likelihood ratio $\chi^2(13)$ was 192.13, Pseudo R^2 value of 0.4180 and Log likelihood of -2203.4075. The results showed that the model fitted the data well (P – Value> χ^2 = 0.00< 0.05). Results indicated that the model was well specified and were fit for inferential statistics (Greene, 2012; Cameron and Trivedi, 2005; Cameron and Trivedi, 2005).

4.2 Test of Hypotheses

Section 4.2.1 presents hypothesis tests on social factors; section 4.2.2 gives the hypothesis test on economic and finally section 4.2.3 present hypothesis test on institutional factors

4.2.1 Hypothesis Test on Social Factors

To determine the effect of social factors (gender, education level, farm experience and family size) on adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County, Kenya. The study sought to establish if social factors such as age, gender, and education level and farmer experience were significantly influencing the adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County. To test this the first hypothesis which stated that social factors such as age, gender, and education level and farmer experience do not significantly influence the adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County. Results from logit regression showed that age had negative and significant effect on the adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County (β= -0.1125, p = 0.0000). This implies that the older the farmer the less likely to adopt new innovations as they stick to their older methods of production. This is consistent with Quddus (2010) and Anderson & Feder (2004) who found out that age is negatively related to technology adoption. This is because households tend to be tied up to the old culture of doing things thus being rigid to new ideas. This can also be referred to as cultural lag in technology adoption.

Farming experience in drip irrigation had also positive and significant effect on the adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County (β = 0.5607, p = 0.0000). Based on these findings it was concluded that social factors such as age, and farmer experience were significantly influencing the adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County. Thus, the first hypothesis was rejected.

These findings support Lapar and Ehui (2004) who identified that small producers who have higher levels of education, higher incomes and access to credit were more likely to adopt dual-purpose forages in Philippines.

4.2.2 Hypothesis Test on Economic Factors

The study sought to determine the effect of economic factors such as farm income, farm size, and off-farm income on adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County. The study sought to determine if economic factors such as farm income, farm size and off-farm income do not significantly influence the adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County.

The results showed that off-farm income had positive and significant coefficient with ($\beta = 0.0254$, $p = 0.0000$). This indicated that off-farm income influences the adoption of drip irrigation by farmers in Subukia Sub County. It further implied that farmers with higher income were more likely to adopt drip irrigation technology.

Based on the results, land size had a positive and statistically significant coefficient with ($\beta = 0.0581$, $p = 0.0411$). This showed that farmers with bigger land sizes were likely to adopt drip irrigation technology. The second hypothesized relationship was economic factors such as farm income, farm size and off-farm income do not significantly influence the adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County. Following the results, the second hypothesis was rejected.

4.2.3 Hypothesis Test on Institutional Factors

To determine the effect of institutional factors such as access to credit, availability of extension services, frequency of extension visits and land tenure on adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County.

Results indicated that access to credit had positive and significant effect on adoption of drip irrigation technology ($\beta = 0.0608$, $p = 0.0040$). This is because farmers who accessed credit facilities were able to acquire drip irrigation facilities such as water reservoir, main line, drip line, drip tapes and other associated accessories. Muthui, (2015) stated that irrigation technology adoption requires reasonable capital investment and which is beyond means of most small scale farmers.

This finding was consistent with Rombo (2013) Rao *et al.*, (2009) REN21 (2005) and Gatahun, Mwangi, Verkuijil and Wondimu, (2000). These results support prior studies by Kabir, Yegberney and Bauer (2013) Mtisi and Makore (2010) that found institutional factors (access to credit and access to extension services) as being significant determinants technology adoption. Ray 2001 argued that extension communication was a necessity in diffusion of innovations.

Access to extension services was also positive and significant ($\beta = 0.0879$, $p = 0.000$). This is because extension services extend and educate farmers on new methods of production. Extension personnel help farmers to understand economic benefits of new innovations such as drip irrigation. They are change agents. This means that extension activities were readily available in the region. This was reflected by the number of extension contacts either through farm visits made or training sessions received during the preceding one-year production season.

Most studies analyzing this variable in the context of agricultural technology show its strong positive influence on adoption (Bonabana-Wabbi, 2002). This study is consistent with a study by Nkonya*et al*., (1997) that found contacts and access to extension services had positive and significant influence on adoption and intensity of technology.

Frequency of extension visits was found to have positive and significant effect on adoption of drip irrigation ($\beta = 0.0291$, $p = 0.0000$). This is because when the farmer is frequently visited the farmer will learn more on the new technology as opposed to where contacts are limited.

Land tenure was also positive and significant determinant of adoption of drip irrigation ($\beta = 0.0098$, $p = 0.0020$). This is because farmers who owned their land were able to use their title deeds as security to obtain credit and invest in long term projects like drip irrigation technology which is a capital intensive undertaking.

Further source of extension knowledge had positive and significant effect on adoption of drip irrigation technology ($\beta = 2.5914$, $p = 0.000$). Studies by Besely and Further, Case (2012b) and Foster and Rosenzweig (2005) using panel data showed that learning from own experience and neighbors' experiences were important factors in determining adoption.

The results of institutional factors support prior comprehensive adoption study by Feder *et al.,* (2005) and Feder and Umali (2003) which showed that farm size, risk, human capital, labour availability, access to credit and land tenure systems were important factors in technology adoption. These findings also support prior study by Ogada *et al.,* (2014) who found that joint adoption of inorganic and improved maize varieties in Kenya is influenced by the use of manure, access to credit, distance to input markets, secure tenure, education and gender of the household head, cultivated area, drainage of the plots, and expected yields. It also agrees with Njabulo, Ntshangase, Muroyiwa and Sibanda (2018).

Similarly, where the government has intervened in strategic promotion of the technology through grants, subsidies and extension service providers there is significant adoption rates as opposed to other areas (Muthui, 2015). Presence of government extension officers in some areas influences information availability to the farmers, credit access, and support to institutions like WRMA and WRUA's play a great role in facilitating adoption (Muthui, 2015).

Based on the above findings and discussions, the third hypothesis that stated that institutional factors such as access to credit, availability of extension services and frequency of extension visits do not significantly influence the adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County was rejected.

CHAPTER FIVE: SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATION

5.1Overview

This chapter presents summary of findings, conclusions and recommendations from the study. The main purpose of this study was to analyze social, economic and institutional factors influencing adoption of drip irrigation technology among smallholder horticultural farmers in Subukia Sub County, Nakuru County, Kenya

5.2 Summary of the Findings

The study carried out descriptive analysis of the variables. The average age of the surveyed farmers was 50 years. Majority (208) of the surveyed households were male. Most of the surveyed households had attained primary level of education and the average family size was found to be seven people per household.

The average farm income was KSh. 7,151 while off-farm income had a mean of KSh. 22,689. The average farm size was found to be 3 acres. The study established that the adoption level was low because majority of the surveyed households (228) did not use drip irrigation while a paltry (49 households) used drip irrigation. The adoption of drip irrigation technology among small-scale farmers is still low despite the proven economic and environmental benefits of the technology (Njabulo*et al.*, 2018) the main type of irrigation was use of sprinkler.

Most of the surveyed farmers (222) accessed credit facilities, while majority of them accessed extension services. The maximum frequency of extension visit was ten times. Majority of the surveyed households (265) owned their lands under leasehold system. None of the surveyed households owned land on communal system showing that in the study area there was no communal ownership of land. The main source of extension knowledge was MoALF.

The study documented that social factors such as age, farm experience and family size affected adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County, Kenya. Economic factors such as farm income, farm size and off farm income influenced adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County.

The study further documented that institutional factors such as access to credit, access to extension services, and frequency of extension visits, land tenure and source of extension knowledge affected adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County.

5.3 Conclusions from the Study

Following hypotheses that were tested the following conclusions were drawn from the study. Social factors such as age, and farmer experience significantly influence the adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County. Therefore, it was concluded that some social factors significantly affect adoption of drip irrigation among small holder farmers in Subukia Sub County, Nakuru County.

Economic factors such as farm income, farm size and land tenure significantly influence the adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County. Therefore, it was concluded that economic factors significantly affect adoption of drip irrigation among small holder farmers in Subukia Sub County, Nakuru County.

Institutional factors such as access to credit, availability of extension service and frequency of extension visits significantly influenced the adoption of drip irrigation technology among smallholder farmers in Subukia Sub County, Nakuru County. Therefore, it was concluded that institutional factors significantly affect adoption of drip irrigation among smallholder farmers in Subukia Sub County, Nakuru County.

5.3.1 Policy Implications

The policy implications of the study are:

The government and other stakeholders should provide incentives for farmers to invest in water-efficient irrigation systems.

The social factors influencing the adoption of drip irrigation technology were determined. Policies should be formulated that improve farmers' knowledge and experiences. This may be done for instance promoting farmers training by introduction of more famers Training Centers and Adult education programs.

The effects of institutional factors influencing the adoption of drip irrigation technology were determined. For land tenure there is need to promote land consolidation programs and planning for better utilization.

5.4 Recommendations

Based on the findings of this research it was recommended that;

i. The Government should enhance farmers' education through adult literacy and extension education so as to improve up-take of other irrigation technologies.
ii. There is need to empower women for better availability of drip irrigation farming.
iii. The Government should introduce cost sharing programs for acquisition of drip irrigation facilities to encourage resource poor farmers acquires them. There is need to encourage farmers through extension education so that they diversify their enterprises, to have other sources of income other than from the farm.
iv. The Government should discourage land fragmentation and encourage land consolidation so as to improve drip irrigation and increase Horticultural

production. This is because drip irrigation farmer with large farms were found to better adapters of drip irrigation technology.

v. There is need for the Government to employ more extension personnel to increase access of the service at the farm household level and provide means of transport to increase the frequency of extension visits to the farmers.

vi. The Government should empower drip irrigation farmers through funding and provision of extension education for knowledge and skill acquisition.

5.5 Suggestions for Future Study

The study did not consider awareness of the benefits of using drip irrigation technology. There is need for a study to consider the level of awareness of the benefits of using drip irrigation among the surveyed households.

The study did not cover other areas that practice drip irrigation technology. Therefore, it is suggested that similar study may be replicated to cover larger areas such as at county level.

The study did not cover the rate of adoption among surveyed household. There is need for a study to be done to consider the rate of adoption of drip irrigation technology.

REFERENCES

Abdulai, A. and Huffman, W.E. (2005). "The diffusion of new agricultural Technologies. The Case of Crossbred Cow Technology in Tanzania *"America Journal of Agricultural Economics*87:645-650.

Adeogun, O. A., Ajana, A. M., Ayinla, O. A., Yarhere, M. T., &Adeogun, M. O. (2008). Application of logit model in adoption decision: A study of hybrid clarias in Lagos State, Nigeria. *American-Eurasian Journal of Agriculture and Environmental Sciences*, *4*(4), 468-472.

Adesina, A.A., and Baidu-Forson, J., (2005). Farmers' perceptions and adoption of new agricultural technology: evidence from analysis in Burkina Faso and Guinea, West Africa. Agricultural Economics 13, 1-9.

Akudugu, M. A., Guo, E., &Dadzie, S. K. (2012). Adoption of modern agricultural production technologies by farm households in Ghana: What factors influence their decisions.

Anderson, J. R., & Feder, G. (2004). Agricultural extension: Good intentions and hard realities. *The World Bank Research Observer*, *19*(1), 41-60.

Azemer, B. (2006). Food Security and Economic Impacts of Small Scale Irrigated Agriculture in Ethiopia, A Case Study of Telltale Irrigation Project in North Shoa Zone, Oromia Region. Unpublished Masters Thesis, Addis Ababa University, Ethiopia.

Barse, K. N., Gohad, V. V., and Lunge, M. R. (2010). "Adoption of drip irrigation system by orange growers in Amravati taluka." *Agriculture Update*, 5(3/4): 346-348.

Bonabana-Wabbi, J. (2002). *Assessing Factors Affecting Adoption of Agricultural Technologies: The Case of Integrated Pest Management (IPM) in Kumi District, Eastern Uganda*. Master of Science Thesis. Virginia Polytechnic Institute and State University. Blacksburg, Virginia.

Bonabana-Wabbi, J. (2002). *Assessing factors affecting adoption of agricultural technologies: The case of Integrated Pest Management (IPM) in Kumi District, Eastern Uganda* (Doctoral dissertation, Virginia Tech).

Bryman, A. and Bell, E. (2007). Business Research Methods; Ventus Publishing: Copenhagen, Denmark; ISBN 978-0199284986.

Burney, Jennifer, Lennart Woltering, Marshall Burke, Rosamond Naylor, and Dov Pasternak. (2010). "Solar-powered drip irrigation enhances food security in the Sudan–Sahel". *Proceedings of the National Academy of Sciences of the United States of America* 107 Washington USA, National academy of sciences.

Busingye, J. D. (2011). *Reducing risk: local knowledge for livelihoods security: a case of Ugandan small holder farmers* (Doctoral dissertation).

Cao, H., Li, Fengmin and He, Xuefeng. (2008). "Factor Influencing the Adoption of Pasture Crop Rotation in the Semiarid Area of China's Loess Plateau." Journal of Sustainable Agriculture 32 (1), pp. 161-179.

Carter, (1994). *Livelihoods and rural poverty*, Cambridge, Cambridge University Press.

Christensen, C. M., McDonald, R., Altman, E. J., & Palmer, J. E. (2018). Disruptive innovation: An intellectual history and directions for future research. *Journal of Management Studies*, *55*(7), 1043-1078.

Cragg, J.G, (1971). Some statistical models for limited dependent variables with application to the demand for durable goods. Economet, 39:829-844.

Daniel, C.N.; Berinyuy, L.P. (2010). Using the SERVQUAL Model to assess Service

Doss, C., and M. Morris. (2001). "How Does Gender Affect the Adoption of Agricultural Innovations? The Case of Improved Maize Technology in Ghana."

FAO, (2005). Farm management glossary *Agricultural Services Bulletin*, FAO, Rome, 221 pp.

FAO. (2009). "The state of food insecurity in the world 2009" *Economic crises – impacts and lessons learned.* Rome, Italy, Food and Agriculture Organization of the United Nations.

Feder, G. & Umali, D.L., (1993). "The adoption of agricultural innovations" *A review*. *Technological Forecasting and Social Change,* Washington, DC 20433, USA

Fernandez-Cornejo, J., Daberkow, S., & Huang, H. (2004). The adoption of IPM techniques by vegetable growers in Florida, Michigan and Texas. *Journal of Agricultural and Applied Economics*, 26 (1), 158-172.

FEWSNET (2010). Status of food insecurity in Kenya.http://www.fews.net

Gashu, D., Demment, M. W., & Stoecker, B. J. (2019). Challenges and opportunities to the African agriculture and food systems. *African Journal of Food, Agriculture, Nutrition and Development*, *19*(1), 14190-14217.

GoK (Government of Kenya) (2011). *Second Report on Poverty in Kenya: Volume 1. Incidence and depth of Poverty*. Ministry of Finance and Planning. Nairobi.

GoK (Government of Kenya). (2012). *National Annual Report*. Ministry of Agriculture. Kilimo House. Nairobi.

Gupta, A. J.; M. F. Ahmad, and F. N. Bhat, (2010). Studies on yield, quality, water and fertilizer use efficiency of capsicum under drip irrigation and fertigation. *Indian Journal of Horticulture*. **67**: 2, 213-218.

Haider, M., & Kreps, G. L. (2004). Forty years of diffusion of innovations: utility and value in public health. *Journal of health communication*, *9*(S1), 3-11.

Hall, B., & Khan, B. (2002). Adoption of New Technology. Retrieved on November 28, 2004 from the World Wide Web: http://elsa.berkeley.edu/~bhhall/Hall_Khan_diffusionJan03.pdf

He, X. F., Cao, H. H. and Li, F. M. (2007). Econometric Analysis of the Determinants of Adoption of Rainwater Harvesting and Supplementary Irrigation Technology(RHSIT) in the Semiarid Loess Plateau of China. *Agric. Water Manage.*,**(89):** 243–250.

Https://www.researchgate.net/publication/280610928_Tomato_Production_Systems_and_Their_Application_to_the_Tropics [accessed Mar 29, 2017].

Irrigation Show (2009). Technical Session Proceedings, Education Conference *Irrigation Association.*

Joshi, P. J. (2004). Extent of knowledge and adoption of farmers about modern practice of cotton in Bhal area of Gujarat. M.Sc. (Agri.) thesis, G.A.U., Anand Campus, Anand.

Kahimba, F.C.; Mutabazi, K.D.; Tumbo, S.D.; Masuki, K.F.; Mbungu, W.B. (2014). Adoption and Scaling-Up of Conservation Agriculture in Tanzania: Case of Arusha and Dodoma Regions. Nat. Resour. 5, 161–176.

Kiruthika, N. (2014). "Determinants of Adoption of Drip Irrigation in Sugarcane Cultivation in Tamil Nadu." *Analysis*, N. Kiruthika, American International Journal of Research in Humanities, Arts and Social Sciences, 5(2): 143-146.

Kongola, E. F. (2018). *Breeding for durable resistance to Cercospora Leaf Spot diseases in groundnuts (Arachishypogaea L.) in Tanzania* (Doctoral dissertation).

Kothari C.R., (2006). Research Methodology Models and Techniques 2nd ed.Newdehli: New international publishers.

Kumar, D. S. (2012). "Adoption of Drip Irrigation System in India: Some Experience and Evidence." *Bangladesh Development Studies,* 35(1): 61-78.

Lapar, M. L. A., Ehui, S. E. (2004). "Factors affecting adoption of dual-purpose forages in the Philippine uplands." *Agricultural Systems,* 81(2): 95-114.

Loevinsohn M, Sumberg J, Diagne A (2012). under what circumstances and conditions do adoption of technology result in increased agricultural productivity Protocol. London: EPPI Centre, Social Science Research Unit, Institute of Education, University of London

Maina, W. N., & Maina, F. M. P. (2012). Youth engagement in agriculture in Kenya: Challenges and prospects. *Update*, *2*.

MoALF (2016). Subukia Annual Report

Mugenda, O., &Mugenda, A., (1999). Research Methods: Quantitative & Qualitative Approaches. Nairobi: Acts Press.

Murray, L., Nguyen, H., Lee, Y. F., Remmenga, M. D., & Smith, D. W. (2012). Variance inflation factors in regression models with dummy variables.

Mutai KB (2001). How to write quality research proposal: Complete simplified recipe. New Delhi: Thelley Publications.

Muthui, M. M. (2015). *Socio-Economic and administrative factors influencing adoption of irrigation technology in Tharaka Nithi county* (Doctoral dissertation, University of Nairobi).

Muthui, M. M. (2015). *Socio-Economic and administrative factors influencing adoption of irrigation technology in Tharaka Nithi county* (Doctoral dissertation, University of Nairobi).

Muzari, W., Gatsi, W., &Muvhunzi, S. (2012). The impacts of technology adoption on smallholder agricultural productivity in sub-Saharan Africa: A review. *Journal of Sustainable Development*, *5*(8), 69.

Namara, R. E., Nagar, R. K., Upadhyay, B. (2007). "Economics, adoption determinants, and impacts of micro-irrigation technologies: empirical results from India." *Irrigation science*, 25(3): 283-297.

Nchinda, V. P., Hadley, D., Villano, R. A., & Morales, E. L. (2020). Assessing the impact of adoption of improved seed yam technology in Cameroon. *The Journal of Developing Areas*, *54*(2).

Ngigi, S, N (1999). "Evaluation of irrigation research and development activities in Kenya", Nairobi Kenya, IWMI

Njabulo Lloyd Ntshangase, Brian Muroyiwa and MelusiSibanda (2018). Farmers' Perceptions and Factors Influencing the Adoption of No-Till Conservation Agriculture by Small-Scale Farmers in Zashuke, KwaZulu-Natal Province. *Sustainability* MPDI.

Nkonya, E., T. Schroeder, and Norman, D. (2007). "Factors Affecting Adoption of Improved Maize Seed and Fertilizer in Northern Tanzania." *Journal of Agricultural Economics*. 48 No. 1**:**1-12.

Nowak, P. (2006). "Practical Considerations in Assessing Barriers to IPM Adoption." Proceedings of the Third National IPM Symposium/Workshop. (Eds.) S. Lynch, C. Green, and C. Kramer-LeBlanc. Washington, DC, USDA-ERS Misc. Pub No. 1542.

Ntshangase, N.L., Muroyiwa B., and Sibanda M., (2018). Farmers' Perceptions and Factors Influencing the Adoption of No-Till Conservation Agriculture by Small-Scale Farmers in Zashuke, KwaZulu-Natal Province, *Sustainability* MDPI.

Ogada, M. J., Mwabu, G., Muchai, D. (2014). "Farm technology adoption in Kenya: a simultaneous estimation of inorganic fertilizer and improved maize variety adoption decisions." *Agricultural and Food Economics*, 2(1): 1-18.

Ongiyo, C. O. (2019). Analysis of socio-economic, factors influencing adoption of biogas technology among farm households in North Rift Region, Kenya. *Africa International Journal of Multidisciplinary Research*, *1*(1).

Oyekale A.S. and E. Idjesa (2009). Adoption of Improved Maize Seeds and Production Efficiency in Rivers State, Nigeria Academic Journal of Plant Sciences 2 (1): 44-50, 2009 ISSN 1995-8986 IDOSI Publications, 2009.

Rahman, H. M., & Hickey, G. M. (2019). What does autonomous adaptation to climate change have to teach public policy and planning about avoiding the risks of maladaptation in Bangladesh?. *Frontiers in Environmental Science*, *7*, 2.

Randall, R. L. (2012). *Socio-economic aspects of irrigation schemes in Kenya, The case of rice production in Mwea irrigation scheme* (Doctoral dissertation, University of Nairobi, Kenya).

Randall, R. L. (2012). *Socio-economic aspects of irrigation schemes in Kenya, The case of rice production in Mwea irrigation scheme* (Doctoral dissertation, University of Nairobi, Kenya).

Republic of Kenya (2013). Medium Term Plan 2013 – 2017.Nairobi

Rogers, E. M. (2003). *Diffusion of Innovations*. Fifth Edition, Free Press, New York, PP. 576.

Rogers, E.M. (1995). Diffusion of innovations (4th Ed.). New York: The Free Press

Sahin, I. (2006). Detailed review of Rogers' diffusion of innovations theory and educational technology-related studies based on Rogers' theory. *Turkish Online Journal of Educational Technology-TOJET*, *5*(2), 14-23.

Saunders, B., Milyavskaya, M., Etz, A., Randles, D., Inzlicht, M., & Vazire, S. (2018). Reported self-control is not meaningfully associated with inhibition-related executive function: A Bayesian analysis. *Collabra: Psychology*, *4*(1).

Sevier, B. J., Lee, W. S. (2004). "Precision agriculture in citrus: a probit model analysis for technology adoption." In The Society of Engineering in Agricultural, Food and Biological systems (ASAE) and The Canadian Society for Engineering in Agricultural, Food, and Biological System (CSAE): 2004 Annual meeting.

Shahzadi, E. (2013). "Investigating Factors Influencing Adoption of Pressurized Irrigation Systems by Farmers Case Study: Garmsar County, Iran." *American-Eurasian Journal of Agriculture and Environment Science*, 13(1): 32-37.

Siele, R. K., Tuitoek, D. K., & Otieno, E. O. (2015). Why housing gap; willingness or eligibility to mortgage financing by respondents in Uasin Gishu, Kenya. *Journal of Emerging Trends in Economics and Management Sciences*, *6*(4), 266-275.

Siele, R. K., Tuitoek, D. K., & Otieno, E. O. (2015). Why housing gap; willingness or eligibility to mortgage financing by respondents in Uasin Gishu, Kenya. *Journal of Emerging Trends in Economics and Management Sciences*, *6*(4), 266-275.

Singh, P. K., Patel, S. K., Trivedi, M. M., Patel, G. R. (2015). "Assessing the relative impacts of the factors affecting MIS adoption process." *International Journal of Sustainable Development & World Ecology*, 22(3): 213-218.

Singh, S. (2020). Farmers’ perception of climate change and adaptation decisions: A micro-level evidence from Bundelkhand Region, India. *Ecological Indicators*, *116*, 106475.

Smit, B., &Pilifosova, O. (2003). Adaptation to climate change in the context of sustainable development and equity. *Sustainable Development*, *8*(9), 9.

Tumbo, S.D., Mutabazi, K.D., Byakugila, M.M., Mahoo H.F.M. (2011). An empirical framework for scaling-out of water system innovations: lessons from diffusion of water system innovations in the Makanya catchment in Northern Tanzania. Agric. Water Manage. 98: 761–1773.

Uddin, M. N., Bokelmann, W., &Entsminger, J. S. (2014). Factors affecting farmers' adaptation strategies to environmental degradation and climate change effects: A farm level study in Bangladesh. *Climate*, *2*(4), 223-241.

Vaezi, L., Daran, H. H. (2012). "Evaluation of the Effective Parameters on Pressurized Irrigation System by Iranian Farmers." *Middle-East Journal of Scientific Research*, 11(1): 39-45.

APPENDIX I: QUESTIONNAIRE

Dear respondent,

My name is Fred Kinyanjui Gatheri; a postgraduate student of Moi University. I am carrying out a research on *"**Analysis of Social, Economic and Institutional Factors Influencing Uptake of Drip Irrigation Technology among Smallholder Horticultural Farmers in Subukia, Nakuru County**"*. With the questionnaires I am collecting data purely for academic purposes. You are kindly requested to provide information required with utmost sincerity. All information given will be treated with utmost confidentiality.

Kindly fill in the questionnaire.

Thanks in advance

Yours faithfully;

Fred Kinyanjui Gatheri

Questionnaire No: …………………………………………………

Sub- scheme: ……………………………………………………

1. What is your age?…………………

2. What is your gender? Male ( ) Female ( )

3. How many are you in the family?..................

4. What is the highest level of education? 1. Primary 2. Secondary 3. Post-Secondary 4. None

5. What is the size of your land?...............

6. What is your land tenure?

Owned ( ) Leased ( ) Communal ( )

7. Do you use drip irrigation technology for crop Production?

Yes ( ) No ( )

b) If No which other technology do you use

Furrow ( ) sprinkler ( ) other specify ( )

8. For how long have you been farming under irrigation…………

9. How much income per year did you get from drip farming in the previous year? Kshs…………

10. How much income do you get from off-farming activity? Kshs…………………

11. How many years have you been doing farming?.......

12. Have you ever received any extension advice on drip irrigation farming in the previous year?

Yes ( ) No ( )

b) If yes, what was the source of extension knowledge?

1. Extension personnel- MoALF
2. Mass media
3. Other source (Specify) ………………………………………………………..

c) How many times were you visited by extension personnel last year?

1. None 2.Once 3.Twice 4.Others (specify)……………….

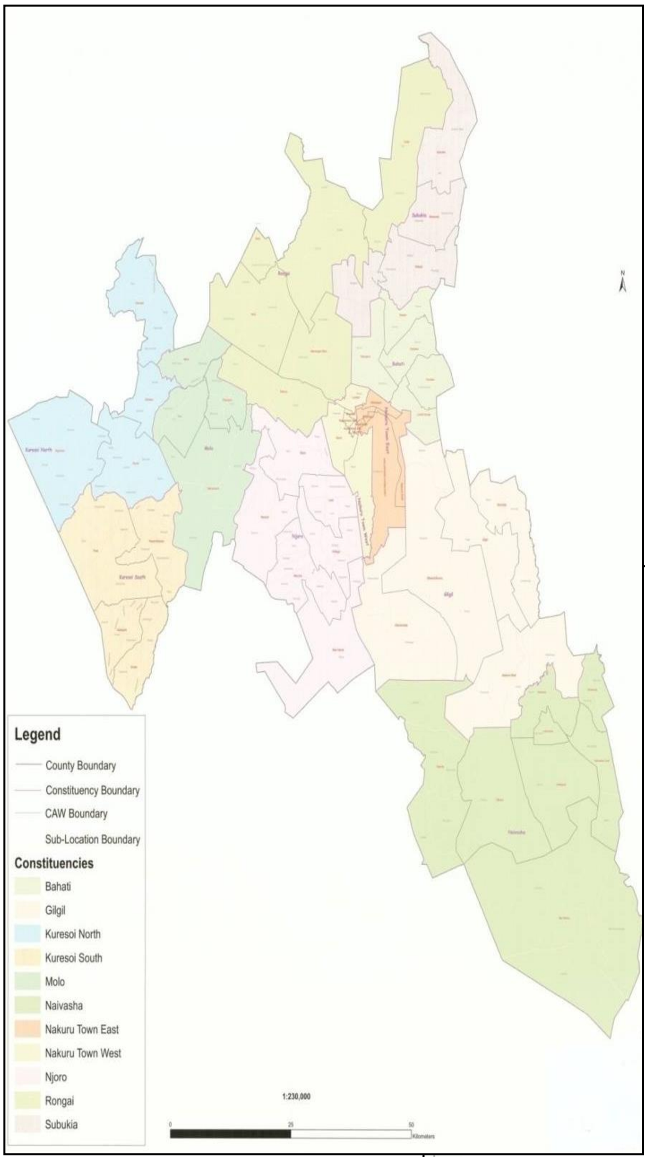
14. Have you ever accessed credit facility?

Yes ( ) No ( )

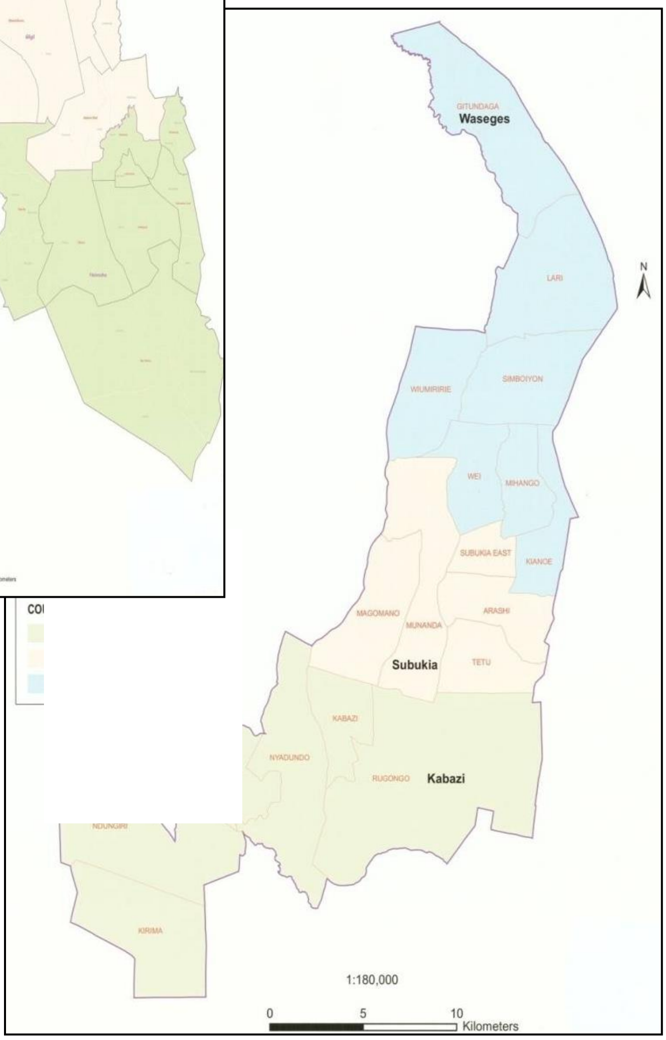
b) Did you use the loan for drip irrigation farming? Yes ( ) No ( )

APPENDIX II: MAP OF THE STUDY AREA

NAKURU COUNTY



SUBUKIA SUBCOUNTY



APPENDIX III: SKETCH MAP OF LARI WENDANI IRRIGATION SCHEME