ADOPTION OF SELECTED CLIMATE SMART AGRICULTURE TECHNOLOGIES AMONG SMALLHOLDER FARMERS IN LOWER EASTERN KENYA

LYDIA NYAWIRA MURIITHI

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL RESOURCE MANAGEMENT OF THE UNIVERSITY OF EMBU

SEPTEMBER, 2021

DECLARATION

This thesis is my original work and has not been presented elsewhere for a degree or any other award.

Signature………………………………… Date…………………………

Lydia Nyawira Muriithi
Department of Agricultural Resource Management
A500/1237/2018

This thesis has been submitted for examination with our approval as the University Supervisors.

Signature………………………………… Date…………………………

Dr. Charles N. Onyari
Department of Land and Water Management
University of Embu

Signature………………………………… Date…………………………

Dr. Hezron R. Mogaka
Department of Agricultural Economics and Extension
University of Embu

Signature………………………………… Date…………………………

Dr. Bernard M. Gichimu
Department of Agricultural Resource Management
University of Embu

DEDICATION

This work is dedicated to my parents for their commitment and passion towards my education and to my siblings who look upon me and whom I hope to inspire.

ACKNOWLEDGEMENT

Sincere gratitude to the Lord Almighty for granting me the grace, good health, endurance, strength, and wisdom that I needed to complete this study. Special gratitude to my supervisors, Dr. Charles Onyari, Dr. Hezron Mogaka, and Dr. Bernard Gichimu for their exemplary guidance, encouragement and unprecedented support during this work. I also wish to extend my heartfelt appreciation to the International Development Research Centre (IDRC) and the Agricultural Mechanization Research Institute (AMRI) through Kenya Agricultural and Livestock Research Organization (KALRO), Katumani-Kenya, for supporting my idea and fully funding my research work. My utmost appreciation to Dr. Kizito Kwena for the perseverance and support accorded to me during data collection, entry, and publication. I appreciate the respondents for their cooperation and hospitality during data collection. Finally, I wish to thank my colleagues, Debra, Kennedy and Amos for their invaluable input towards this research.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

ASALs	Arid and Semi-Arid Lands
ASDP	Agriculture Sector Development Support Programme
CA	Conservation Agriculture
CSA	Climate Smart Agriculture
DO1	Diffusion of Innovation
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GoK	Government of Kenya
FCS	Food Consumption Score
ICRAF	International Centre for Research in Agroforestry
ICT	Information and Communications Technology
IDA	International Development Agency
IPCC	Intergovernmental Panel on Climate Change
KALRO	Kenya Agricultural & Livestock Research Organization
KCSAP	Kenya Climate Smart Agriculture Project
KFS	Kenya Forest Service
KMD	Kenya Meteorological Department
MNL	Multinomial Logistic
MVP	Multivariate Probit
NGO	Non-Governmental Organization(s)
ODK	Open Data Kit
SDGs	Sustainable Development Goals
SSA	Sub-Saharan Africa

OPERATIONAL DEFINITION OF TERMS

Climate change adaptation	Adjustments made to natural and human systems as a response to actual and expected changes in climatic conditions in an attempt to moderate harm or to cope with the consequences (IPCC, 2001).
Adaptation	Responses by individuals, groups and governments to actual or expected changes in climatic conditions or their effects (FAO, 2008).
Adaptive capacity	Ability to adjust successfully to climate change and variability extremes, moderate potential damages while taking advantage of available opportunities and coping with the consequences of change (IPCC, 2007a).
Adaptation information	Information prepared and disseminated to farmers on appropriate technologies, agronomic practices and other responses to be adopted by farmers to get the best from any season (IPCC, 2014).
Adoption	Process of accepting a new innovation based on the demographic and psychological characteristics of a defined adopter group or individual (IPCC, 2014).
Climate change	Long term changes in the weather patterns over a given period of time caused either by natural processes or human activity, for instance, erratic rainfall, increasing temperatures and extreme drought conditions (IPCC, 2007b).
Climate Smart Agriculture	Agricultural technologies, innovations and practices that sustainably increase productivity and incomes, increase resilience to climate change, reduce emission of greenhouse gases and enhance achievement of the national food security (FAO, 2015).

Climate variability	Variations in the occurrence of extremes of the climate on all temporal and spatial scales beyond that of weather events. It may result either from natural internal processes within the climate (internal variability) or from variations in natural or anthropogenic external force (external variability) (IPCC, 2001).
Farmer perceptions	The manner in which a farmer sees, hears or is aware of something or a situation (IPCC, 2007b).
Food security	Situation when all members of a household at all times have physical, social and economic access to safe and nutritious basic foods that meet dietary needs and food preferences for an active and healthy life (IPCC, 2014).
Institutional factors	Includes all those factors that are beyond the control of households for example, credit issues, extension services, markets, and a particular system under which land is owned and managed to have a direct bearing on agricultural productivity and efficiency (FAO, 2018).
Mitigation	Interventions to reduce or prevent of greenhouse gases sources and emissions and enhance greenhouse gas sinks (IPCC, 2001).
Resilience	Capacity of systems, communities, households or individuals to prevent, mitigate or cope with risk and recover from shocks (FAO, 2013).
Semi-arid	Areas receiving an annual rainfall of about 25 to 51 centimeters per annum (FAO, 2015).
Smallholder farmers	Farmers with farm sizes of less than or equal to 5 hectares on which subsistence or one to two cash crops are grown by relying on family labor (FAO, 2018).
Socio-economic factors	Lifestyle components and measurements of both financial viability and social standing which directly influence social privilege and levels of financial independence (FAO, 2018).

ABSTRACT

Climate change has greatly affected food production and food security. Erratic temperature rises and inconsistent precipitation have greatly influenced productivity of crops and livestock. The impacts have gotten much more pronounced among small scale farmers in Kenya whose farming activities are climate reliant. As a component of climate change adaptation, selecting suitable climate smart agriculture (CSA) technologies that can alleviate these adverse consequences is critical. The study sought to determine the factors affecting adoption of selected climate smart agriculture technologies among smallholder farmers in Lower Eastern Kenya, comprising of Machakos, Kitui and Makueni Counties. A sample of 384 households was obtained using multi-stage sampling procedure. A semi-structured questionnaire designed in an open data kit (ODK) application was used to collect primary data from the sampled smallholder farmers. The main adaptation technologies considered were mixed farming, intercropping, crop rotation, conservation agriculture, agroforestry, crop diversification and water harvesting, in that order. Descriptive statistics (frequency and percentages) were used to analyze socio-economic characteristics. Findings revealed that 54.2% of the respondents were males and 35.7% in their productive years (36-50 years). In addition, the findings revealed that most of the interviewed farmers (97.4%) had observed climate change and the effect on food production. Results of the multinomial regression on socio-economic and climate information pathways revealed a positive impact of gender and education level on uptake of crop rotation (0.7%), agroforestry (0.9%) and crop diversification (0.4%) while reliance on mobile phones (0.9%) and neighbors/friends (0.2%) reduced adoption of water harvesting. Multivariate probit model was employed to analyze socio-economic and institutional factors influencing adoption. The likelihood of adopting mixed farming, intercropping and crop rotation significantly increased ($p<0.05$) among male-headed households and having adequate access to off-farm income and credit facilities. Further, a Food Consumption Score (FCS) was employed to compare quantity and quality of food consumed among households across the three counties. Kitui County had the highest poor FCS at 80% due to lack of adequate knowledge on proper use of the technology than was the case in Kitui (72.5%) and Makueni (73%) Counties. This study therefore recommends promoting adoption of the disseminated CSA technologies, providing reliable extension services plus accessibility to other essential services, like, fertilizer and seeds markets for realizing increased agricultural production in Lower Eastern Kenya.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Climate change has greatly affected agricultural production and peoples livelihood (Makate, 2019). It is widely accepted that, containing environmental change pace by keeping temperature ascend within 2°C threshold over the long haul, is a serious challenge and the worldwide population has to deal with its consequences (IPCC, 2014). Climate change impacts, for example, changes in precipitation patterns and rising global average temperatures are evidently clear with impacts on biodiversity, environment and human frameworks all through the world. Among the numerous impacts, production of adequate food is considered as the major challenge (World Bank, 2013).

Worldwide, 1.7 billion farmers are extremely vulnerable to climate change impacts (Misra, 2014). Of these farmers, 837 million live in Asia and 228 million in Africa (Ford *et al*., 2015). The world population depending on agricultural production systems is projected to reach 9.1 billion individuals in 2050 and more than 10 billion by the end of the century (World Bank, 2011). Most farmers in Africa live in rural lands having delicate soils, low precipitation, slanting landscapes and poor market access (Jarvis *et al*., 2011). Their susceptibility to environmental change impacts is already high as most of them have little savings and few alternative options to help mitigate adverse climate change impacts (Munang *et al*., 2013).

Africa is becoming the most risky continent to climate change impacts due to its high reliance on rain-fed agriculture, low precipitation, hotter baselines and limited technology adoption (Partey *et al*., 2018). Over the last century, Africa has warmed about half a degree and the average yearly temperatures by 2099 are estimated to increase by an average of 1.5 - 4°C (IPCC, 2014). Evidences from the Inter-Governmental Panel on Climate Change (IPCC) fourth evaluation report show that the greater part of the Sub-Sahara regions are likely to experience agricultural losses ranging between 2 and 7% Gross Domestic Product (GDP) equivalent by 2100 (IPCC, 2007a). These impacts will happen alongside high population expansion in areas projected to rise from 0.9 billion individuals in 2005 to around 2 billion by 2050 (Clark *et al*., 2020). The situation is more critical in the drier parts of Africa, popularly known as Arid and Semi-Arid Lands (ASALs), where populations are becoming more exposed to hunger, malnutrition, and poverty (Kotir, 2011).

In Kenya, the agricultural sector provides for rural communities livelihoods as is the case with most developing countries (Mutenje *et al*., 2019). It contributes about 26% of Kenya's GDP directly and 27% indirectly through linkages with manufacturing, distribution and other service-related sectors. Additionally, over half of the population is employed in the sector, with more than 70% residing in rural areas (FAO, 2018). Due to these reasons, the Government of Kenya (GoK) has continued to prioritize the sector in its development strategies. The Vision 2030 blueprint, for instance, aims at increasing agricultural GDP through innovative means, commercially oriented and modern agriculture (Kogo *et al*., 2021). This can only be achieved by understanding the farming technologies adopted by farmers and the drivers of the adoption behavior.

Food sufficiency and security in Kenya is a long-term goal which remains unmet. Food security is realized when all individuals have physical, social and economic access to safe and nutritious basic foods that meet dietary needs for an active and healthy life (WHO, 2019). According to KNBS (2019), about 70% of the population lives in rural regions and 29.2% of those living in metropolitan regions are poor. Additionally, poverty rates in arid and sparsely populated areas of North-Eastern are estimated to remain above 70% (UNDP, 2011). The report further uncovers that increased prices of food and non-food items, livestock diseases, conflicts and crop failures have led to increased food insecurity in the Kenyan ASALs (Amwata *et al*., 2016) This clearly indicates that a greater part of small scale farmers living in Kenyan dry lands are potentially hungry and vulnerable to food shortages.

Recently, some approaches have been developed in an attempt to respond to climate induced risks and impacts across African communities (Vermeulen *et al*., 2012). Due to the increasing social, environmental and economic issues arising from variations in climatic conditions, the Malabo declaration on CSA Vision 25 x 25 was adopted in Africa (Kuntashula *et al*., 2017). The initiative aims to support around 25 million farming households practicing CSA by 2025 (Girvetz *et al*., 2015). The CSA approach targets to improve natural resources efficiency, build resilience of livelihoods and minimize greenhouse gases (GHGs) emissions so as to enhance national food security (Imran *et al*., 2018). Therefore, individual adoption of CSA technologies in Kenya and Africa can greatly reduce the adverse climate change effects.

Climate change in Lower Eastern Kenya, that is, Makueni, Machakos and Kitui Counties, is evident through poor crops and livestock production (Kichamu *et al*., 2018; Ndung'u *et al*., 2021). Frequent droughts in the regions have more often than not led to food-aid interventions from the government as well as development partners (Lalani *et al*., 2016). Over the last decade, the percentage of undernourished persons in the three Counties was estimated to be 39.4%, as compared to the national average of 32% (Makate *et al*., 2019). The author further notes that the County Governments noticed that heavy flooding in some low-lying regions led to very poor production of crops and some cereals in several sub-counties.

FAO (2010), notes that CSA practices are appropriate methods of building resilience among smallholder farmers as well as reducing environmental degradation. The County Governments through the Ministry of Agriculture and Livestock collaborates with organizations like International Development Agency (IDA-World Bank Group), Agriculture Sector Development Support Programme (ASDP), Kenya Agricultural and Livestock Research Organization (KALRO), Kenya Meteorological Department (KMD), Kenya Forest Service (KFS), International Centre for Research in Agroforestry (ICRAF) and Kenya Climate Smart Agriculture Project (KCSAP) to increase agricultural production and enhance resilience (Mwadalu & Mwangi, 2013; Masesi, 2019). Some of the strategies include adoption of drought-tolerant varieties, promotion of water conservation technologies, crop insurance, crop rotation, intercropping, conservation agriculture (CA), weather agro-advisories, use of cover crops, and seasonal climate forecasts (Lipper *et al*., 2014). Their findings also observe that enhancement of extension services, climate change education and value addition are also widely promoted.

Factors influencing adoption of CSA technologies vary with people and region (Roco *et al*., 2014). However, the causes of low adoption of appropriate CSA technologies in the Counties of Kitui, Makueni and Machakos still remains unclear (Kalungu and Leal Filho, 2018). There has been little focus on innovative dissemination and adoption of proven technologies which should enable farmers adapt easily to climate change (Gebrehiwot & Van Der Veen, 2013). For any given adaptation option, there exists a vector of environmental, socio-economic and institutional aspects that may drive its adoption. The knowledge on these factors is vital in providing scientific evidence and actions for minimizing household food insecurity and enhancing resilience to climate change (Asayehegn *et al*., 2017). Hence, this study analyzed certain factors influencing adoption of selected CSA technologies in Lower Eastern Kenya so as to enhance household food security as well as contribute positively to the rural livelihoods.

1.2 Statement of the Problem

Climate change being experienced globally has negatively affected agricultural production. The agriculture sector has greatly contributed to the Kenyan economy through food production. However, agriculture in Kenya is almost entirely rain-fed hence being most vulnerable to global climate change risks and impacts. The changing climatic conditions have led to drastic reduction in agricultural production on which most of the Kenyan population relies on for their survival. The low adaptive capacity among the poor populations also contributes to the increased climate change and vulnerability in the country. In this respect, application of CSA technologies is vital in reducing the interlinked problems of food security and climate change. Research has been done on climate adaptation strategies, but little has been reported on CSA and its preference in the rural communities of Kenya. Moreover, studies indicate that agriculture in Lower Eastern Kenya is characterized by low adoption of disseminated CSA technologies, yet documented data to inform policy is scanty. Government and development partners in lower Eastern Kenya continue to encourage uptake of CSA technologies, but there is considerable evidence on factors constraining use of CSA technologies so as to enhance food production and general crop performance. The study therefore sought to evaluate the factors influencing adoption of selected CSA technologies by the small scale farmers in Lower Eastern Kenya so as to improve on their farming capacities.

1.3 Justification

Farm level adoption can greatly reduce vulnerability to climate change by making rural communities able to adjust to the changing climate, cope with adverse consequences and moderate potential damages. The Lower Eastern Counties of Makueni, Kitui and Machakos experience drought and erratic rainfall regularly coupled with low adoption of CSA technologies. Adaptation to climate change is therefore a necessary climate action to help mitigate, assess perceptions and allow determination of factors affecting adaptation at the household level. In order to adequately address the issues of climate change through adoption of CSA technologies, a lot of information systems, advocacy, research and adoption strategies are required. Therefore, the knowledge on climate change adaptation information, institutional and socio-economic factors influencing adoption of CSA technologies is one stage towards households achieving an optimal solution in farming practices. This will be advanced in the Counties' strategic plans through addition of response measures improving farmers' resilience in agribusiness performance. The results of this study provides a reference on the significance of adopting CSA technologies by farmers and provide avenues for further research in the area.

1.4 Research Questions

1. How does climate change adaptation information influence adoption of selected climate smart agriculture technologies in Lower Eastern Kenya?

2. What are the socio-economic and institutional factors influencing adoption of multiple climate smart agriculture technologies in Lower Eastern Kenya?
3. How does adoption of selected climate smart agriculture technologies influence food security among smallholder farmers in Lower Eastern Kenya?

1.5 Research Objectives

1.5.1 General Objective

The general objective of the study was to assess the factors influencing adoption of selected climate smart agriculture technologies among smallholder farmers in Lower Eastern Kenya.

1.5.2 Specific Objectives

1. To evaluate the influence of climate change adaptation information on the adoption of selected climate smart agriculture technologies in Lower Eastern Kenya.
2. To analyze the influence of socio-economic and institutional factors on adoption of multiple climate smart agriculture technologies in Lower Eastern Kenya.
3. To evaluate the effect of adopting selected climate smart agriculture technologies on food security among smallholder farmers in Lower Eastern Kenya.

1.6 Significance of the Study

The study findings add to the existing body of scientific information on the factors that influence the adoption of climate smart agriculture technologies in the drier parts of Kenya with specific reference to Makueni, Machakos and Kitui Counties. Secondly, the evidence generated is a major input in the planning and policy development processes in the three Counties. Thirdly, the findings of the study will assist farmers and farming organizations to have adequate access to information on the most important and viable climate smart practices which will mainstream productivity and lead to achievement of food security. The thesis is an important part of the requirements of the award for of the Master of Science degree in Agricultural Resources Management.

CHAPTER TWO
LITERATURE REVIEW

2.1 Overview

The chapter presents earlier readings on climate change and variability, its effect on small scale agricultural production, kinds of information sources used to relay climate adaptation messages, the idea of climate smart agriculture and its impact on household food security status. Additionally, some socio-economic and institutional factors were explored to determine their impact on adoption of various agricultural practices. The reviews in the existing literature led to some knowledge gaps. Lastly, there was a review of the diffusion of innovation theory on which the study was anchored.

2.2 Climate Change as a Concern in Agriculture

Climate change and agriculture are interrelated processes. Their occurrence at a global scale poses continuous imbalances between the global population and food production levels. Climate change impacts and consequences tend to be more severe in numerous regions of the developing world particularly Sub-Saharan Africa and South Asia. Lobell *et al*. (2008) studied twelve food-insecure regions of the world and reported severe climate change impacts on food production and food security up to the year 2030 due to variations in mean temperatures and rainfall. World Bank (2009), studied the aridity levels in Morocco and found out that continuous reduction in rainfall levels and higher temperatures negatively impacted agricultural yields. A study in Brazil also reported severe impacts on crops like cotton, rice, coffee, millet, soybean, sunflower, cassava and beans due to increased evapotranspiration rates (Bustos *et al.*, 2016).

The lower Eastern parts of Kenya experience climatic variability which manifests in climate extremes like floods and droughts (Khisa & Oteng, 2014). Rising temperatures, changes in rainfall patterns and increased intensity of ‘extreme events’ within the regions significantly affects food security through shifts in crop growing seasons and changes in the distribution of pests and diseases (IPCC, 2007a). Increasing adaptive capacity in such regions will not only meet the SDG one (no poverty), two (zero hunger) or thirteen (climate action), but also ensure reduced vulnerability to weather shocks increase in the future (UN, 2019).

2.3 Climate Change Adaptation Information

Adaptation has been considered by many as the most effective method of minimizing negative climate change impacts. It entails changes in the natural and human systems to moderate harm that may have in any case happened (IPCC, 2001). According to World Bank (2008), successful adaptation depends on factors such as availability of knowledge and information, technical capability, financial, institutional and natural resources. Additionally, numerous social, economic, technological and environmental trends basically shape ability to perceive and adapt to climate change (WMO, 2018). Knowledge of the factors affecting farmers' choices and appropriate adaptation methods is vital in enhancement of efforts directed towards tackling the challenges that climate change is imposing on farmers (Beddington *et al*., 2016).

There are two recognizable adaptation types namely planned and spontaneous (IPCC, 2012). Planned adaptation involves a society that is guided by specific policies while spontaneous adaptation happens within an individual. Climate change has greatly affected agriculture and most growth prospects in lower latitudes (Nunes *et al*., 2014). The threats involved range from inadequate food access by both rural and urban areas, reduced agricultural incomes, increased risks and market disruptions (Gupta *et al*., 2021). Thus, inclusion of numerous stakeholders, including farmers, policy makers, extension agents, Non-governmental organizations (NGOs), researchers, and the private sector significantly influences ways through which rural communities can maintain food, income and livelihood security.

In most of the poor countries, rural communities are more prone to adverse climate change impacts and socio-economic conditions than those in urban areas (Reidsma *et al*., 2010). Creation of awareness and dissemination of appropriate information among the smallholder farmers is facilitated by various channels of communication. According to

Akudugu *et al*. (2012), some of the frequently used channels include the mass media channels such as radio, television; group media like the seminars, agricultural shows and farm demonstrations; print media such as posters, books, brochures; interpersonal mediums like person-to-person contact and information communication technologies (ICTs) like E-mails. The channels are highly dependent on quality of the communication infrastructure, media richness, message characteristics and availability of a feedback mechanism (WMO, 2018). Therefore, intensification of climate information collection, sharing and dissemination through the available sources and pathways is significant in ensuring timely conveyance of agricultural information to the intended targets (Nxumalo & Oladele, 2013).

2.4 Climate Change Adaptation Information and CSA Technologies

Agricultural vulnerability to climate change is currently a major challenge affecting sustainability of food systems. In response to climate change, farmers' perceptions have greatly influenced the adoption of technologies like the use of improved seeds, and ICT based agro-advisories (Saylor *et al*., 2016). A study by Habiba *et al*. (2012) showed that understanding farmers' concerns facilitated formulation of effective policies that promoted designing of successful adaptation measures to climate change since farmers concerns and needs were incorporated. Similarly, Efole *et al*. (2017) noted slow adoption towards fish farming in Cameroon since most farmers were not conversant with the aquaculture technology due to inadequate information on effective and efficient production, value addition, and marketing. Increasingly, it is becoming clear that technology designers provide adequate information along the entire technology-continuum from production to waste management. It is important to introduce and involve farmers at all stages when evaluating the suitability of a given technology so as to ease its adoption (Arbuckle *et al*., 2015).

Failure of farmers to identify useful adaptation strategies which are related to climate change risks hinders adoption of CSA technologies. Small scale farmers tend to have fewer interactions with dissemination pathways like agricultural extension agents, local administrators and mass media which in turn negatively affect agricultural productivity (Emmanuel *et al*., 2016). Additionally, Belay *et al*. (2017), discovered that interaction of farmers with extension agents from the local government and NGOs in Ethiopia, enabled easy identification of appropriate agricultural technologies like crop diversification and soil and water conservation practices which led to increased productivity in the area. Ngigi *et al*. (2017), also reported increased agricultural productivity due to dissemination of relevant information and access to training programs.

Willingness of farmers to implement the necessary climate change adaptation responses greatly influences agricultural productivity. Studies by Shadreck *et al*. (2013) on practical innovation initiatives have revealed that the nature of response by farmers depends on the extent of exposure to the stress, the properties of the affected system and the extent. Bryan *et al*. (2009) argue that the willingness to adapt to climate change and variability primarily depends on time-horizon, individual decisions as well as the experience on climate hazards. Therefore, analyzing the adaptive capability of farmers to climate smart agriculture technologies should take into account the analysis of various factors promoting adoption (Bryan *et al*., 2013) . Evaluating variables that impact adoption of specific CSA technologies in Lower Eastern Kenya was vital in improvement of overall food security (Shankar & Shikha, 2017) and returns to investment at the farm level.

2.5 Selected Factors Influencing Adoption of CSA Technologies

The low adoption rates of various agricultural technologies and innovations in Kenya have been shown to depend on various socio-economic factors (Oganda *et al.*, 2014). At the household level, gender influences adoption of CSA technologies and achievement of sustainable food security (Ngigi *et al*., 2017). The interaction between gender and climate change determines the roles of male and female-headed households in technology adoption (Lipper *et al*., 2014). It affects decision making in that men have a greater control over vital production resources than women due to socio-cultural values and norms (Nambiro & Okoth, 2013). Manda *et al*. (2016), found high uptake rates of CA technology among male farmers as compared to female farmers. In other instances, women may not make decisions but influence those decisions. This relates to studies done in Cameroon and Mali which indicated that for many cases where there is heightened levels of agricultural technology adoption, men had to involve the women folk for increased labor supply (Wainaina *et al*., 2016). This is important given that family labor where women contribute the most is key in subsistence farming in Africa.

Additionally, farm size and affects adoption in that, large scale farmers who would be less risk averse are likely to devote part of their land for trial of a new technology (Deressa *et al*., 2009). Makate *et al*. (2018), also identified that small scale farmers who adopt labor intensive technologies and rely on family labor obtain a low opportunity cost. Other studies, for instance, Lalani *et al*. (2016), holds an alternative view that large scale farmers are more likely to adopt adaptation practices since capital and assets will aid in strategies demanding high investment cost. In respect to tenure, it is common for farmers with secure title deeds or secure resource tenure systems to have long term investments in SA technologies at the farm level (Mittal & Mehar, 2016).

Manda *et al*. (2016), examined the impact of age on adoption of agricultural technologies and found a composite effect on farming experience and planning. It is assumed that older farmers have acquired adequate information and experience over time hence being better evaluators in case a new technology arises as compared to younger farmers (Fisher & Carr, 2015). On the contrary, Totin *et al*, (2018) showed that older farmers have a short time horizon in making decisions and adopting the climate-smart push-pull technology unlike younger farmers with a long time horizon that enables them make fast decisions and adopt the recommended technologies. All these varied effects of age may be due to the type of technology being introduced. With ICT becoming part of every sector's management, it is interesting to find out how age influences the adoption of emerging and climate change responsive technologies (Khatri-chhetri *et al*., 2016).

Moreover, the level of education among farmers greatly influences decision making in the uptake of CSA technologies (Adebiyi & Okunlola, 2013). Farmers who are better educated and experienced have a higher ability to obtain, process and use farm level decisions on the type of technology. A study by Mariano *et al*. (2012), sought to find out the adoption rates of modern rice varieties in Philippines. Their findings illustrated a high investment capability among educated farmers than less educated ones. Understanding education level among farmers will help determine the specific types and dissemination methods of agricultural technologies depending on the education category (Meijer *et al*., 2015).

Off farm income can positively or negatively influence technology adoption. It is important in overcoming rural credit constraints since farmers will have access to farm inputs like improved fertilizers and seeds. Empirical evidence by Baumgart-getz *et al*. (2012) illustrated a high uptake of farming technologies among farmers with sufficient financial wellbeing. In spite of this, Uddin *et al*. (2014) noted a negative relationship in crop insurance adoption due to poor management of financial institutions in Bangladesh.

The landscape of institutional factors that influence adoption of SA technologies is large and therefore for the purpose of addressing the study objective, the focus was on markets, credit facilities, and resource ownership. Accessibility to local markets by smallholder farmers is key in ensuring easy availability and supply of food among households (McCubbin *et al*., 2017). In most of the rural areas, poor infrastructure network hinders farmers' ability to transport goods, resulting to increased market prices (Mottaleb *et al*., 2016). A study by Nambiro & Okoth (2013), noted a decline in off farm adaptations due to long distanced markets which hindered farmers' ability to congregate and share information. Market information may greatly have an influence on the investment farmers are willing to set a side or devote to adoption of CSA technologies. With increasing use of ICT, market information on various farm outputs would be made available to farmers (Ernah *et al*., 2016).

Credit facilities are integral in the process of commercializing rural economies and addressing poverty (Etwire *et al*., 2013). Accessibility to credit facilities by smallholder farmers not only removes financial constraint but also accelerates uptake of new technologies (Shiferaw *et al*., 2014). A study by Ramirez (2013), observed a positive relationship between adoption level of water conservation technologies and credit availability since most rice farmers adopted use of lacer land levelers to conserve water. In some countries, there are low adoption rates of yield-raising technologies since female headed households are discriminated by credit institutions (Harvey *et al*., 2014).

Moreover, technology awareness among smallholder farmers influences speed of adoption among smallholder farmers (Hellin *et al*., 2014). Dissemination of appropriate climate change information by agricultural extension officers' enables farmers learn more about the existence of a new technology, evaluate its pros and cons and finally decide whether to adopt or not. Ssentamu *et al*. (2012), observed that awareness of farmers on climate change attributes, either temperature, or precipitation or both is of essence in adoption of tissue culture banana technology. Understanding the methods of technology information transmission is an important aspect to aid in faster adoption of SA technologies (Asfaw *et al*., 2012).

Land ownership also determines adoption of land management practices (Bravo *et al.*, 2016). The implications on property rights and long term investments in climate change adaptation strategies greatly influence ability of small holders to adopt new farming techniques (Chhetri *et al*., 2012). For instance, adoption of some technologies like soil conservation practices and irrigation equipment's is greatly influenced by tenure security (Mottaleb *et al.*, 2016). In large scale production, the cost of conservation measures is reduced as compared to small scale farmers due to economies of scale, thus important to encourage high land management investments (Namara *et al*., 2013). Failure of farmers to capture most of the economic incentives and invest their time or money greatly influences overall productivity at farm level (Shiferaw *et al.*, 2014). This study aimed at evaluating the influence of specific socio-economic and institutional factors on adoption of multiple technologies in Lower Eastern Kenya so as to improve food security among the rural households and beyond.

2.6 Effects of Adopting Selected CSA Technologies on Food Security

The idea of food security has over time been utilized at the family level in measurement of wealth (Lobell & Gourdji, 2012). Households are considered to be food secure if there is enough economical and physical accessibility to food by everyone, everywhere, and every time (WHO, 2019) . Amwata *et al*. (2016), defines food security as having adequate diet lasting through the year for functioning solid life (that is, 2250 kcal/AAME/day). Different studies, for example, that of Golub *et al*. (2013), state that food security is achieved through attainment of enough growth in food crops and livestock which maintains yield per individual, reduces food calorie shortages and imports.

According to WFP (1996), food security definition revolves around three distinct but interrelated elements which are essential in achieving household food and nutrition security. The pillars include food availability (production, distribution, and exchange), food access (affordability, allocation, and preference) and food utilization (food safety, nutrition and social value). Also, FAO (2011), notes that for food security to exist, stability should be present "at all times," in ensuring availability of calories and sufficient worldwide production, accessibility of enough food by the rural households everywhere, physically and economically is vital.

Food insecurity which is a major development challenge in many countries including Kenya, has prioritized the issue in her top four agenda (Lobell & Gourdji, 2012). Rigolot *et al*. (2017), noted increased adoption levels of crop-livestock diversification in Burkina Faso which slowed down spread of pests and diseases and increased productivity. Kalungu and Leal Filho 2018, also noted high food insecurity among smallholder farmers in Kenya due to high inconstancy of precipitation amidst rising temperatures. Further, Serdeczny *et al*. 2017; Hadush 2018, also noted that most communities in sub-Saharan Africa experience shortage of water and pasture for the greater part of the year as most of them live in economically poor and marginal regions.

CSA addresses food security through transformation of agricultural systems through the use of improved seeds and fertilizer (Lipper *et al*., 2014). Additionally, appropriate policies and investments within the agricultural sector can move into CSA pathways, thus minimizing food insecurity and poverty in the short term (Aryal *et al*., 2020). Therefore, determining transformation methods within the agricultural systems is key in enhancement of worldwide food security (Abid *et al*., 2015). The study seeks to identify impacts of selected agricultural technologies on Lower Eastern small scale farmers' and in improvement of the overall agricultural productivity.

2.7 Research Gap

Some studies (Boruru *et al*., 2011; Simotwo *et al*., 2018; Wassmann, 2019), have covered the potential effects of climate change on Kenyan agriculture and methods of adjusting to climate change. These investigations by and large demonstrate that farmers can cope with adverse climate change impacts by implementing adaptation measures. Nevertheless, most of them failed to point out the factors affecting decisions on the recommended adaptation methods. There are also a number of studies (Ayuya *et al*., 2012; Dulal *et al*., 2010) that just recognized household farm attributes and institutional issues as the critical determinants of adoption. Rogers (2010) upholds that technology knowledge and attitude determines farmers' choices and actions during adoption or practice. Similarly, the adopter perception model stipulates that adoption process begins with perceiving the problem and technology under consideration. In situations where selection of innovations has failed, findings by Dzanku *et al*. (2011) and Howley e*t al*. (2012) have attributed this to limited knowledge, but failed to illustrate explicit knowledge gaps and the causes of limited knowledge.

Availing timely and correct climate change adaptation information to the farmers has been viewed as a basic preparation and adaptation to uncertainties and risks. However, few studies (Murgor *et al*., 2014; Cherotich *et al*., 2012) have investigated the level of dissemination and access of appropriate and timely climate information among the small scale farmers in lower Eastern region in the achievement of the household food security status. There is need to evaluate the level of outreach and dissemination pathways that impact adoption of specific CSA technologies so as to decide proper measures for strengthening access and utilization of climate information for enhanced adoption at the household level.

2.8 Theoretical Framework

Diffusion of Innovation (DOI) theory has guided numerous studies trying to understand adoption of new agricultural technologies. Hence, this study was guided by the DOI theory advanced by Rogers (2010). The theory explains communication channels (mass media, interpersonal communication) and processes additional channels (social systems, time) that are appropriate in diffusion of modern technologies to the community. Professionals in various disciplines, that is, agriculture to marketing, have utilized this theory to intensify adoption of innovative products and practices (Meijer *et al*., 2015).

According to Rogers (2010), the major factors influencing diffusion of innovation include time, nature of the social system through which the innovation is introduced, medium of information communication and the characteristics of the innovation itself. Rogers (2010), further proposed that the innovativeness of an individual determines when the individual adopts the innovation and recognized five successive adopter categories: innovators, early adopters, early majority, late majority and laggards. The adoption process is also affected by the so-called receiver variables, such as personality characteristics, social characteristics and the perceived need for the innovation.

In this study, DOI was used in explaining why, what and how the speed of new climate smart agricultural technologies was communicated through existing social systems and firm levels as well. The concept of technology use was important in the study to illustrate all new technologies disseminated to smallholder farmers for adoption through a natural, predictable and lengthy processes influenced by various factors. Diffusion among Lower Eastern Kenya small scale farmers was also seen in five stages, that is, potential adapters of a given technology learning about it, being persuaded on the merits, deciding whether to adopt, implementing and making the decision to adopt.

2.9 Conceptual Framework

The study sought to establish various factors influencing adoption of selected CSA technologies in Lower Eastern Kenya. Figure 2.1 depicts links between climate change adaptation information plus selected socio-economic and institutional factors influencing adoption so as to ensure food security among households. Low agricultural production would be attributed to low adoption of selected CSA technologies. Adoption of selected CSA technologies was the dependent variable while adaptation information pathways, socio-economic and institutional factors were the independent variables, and the improved food security was the expected output.

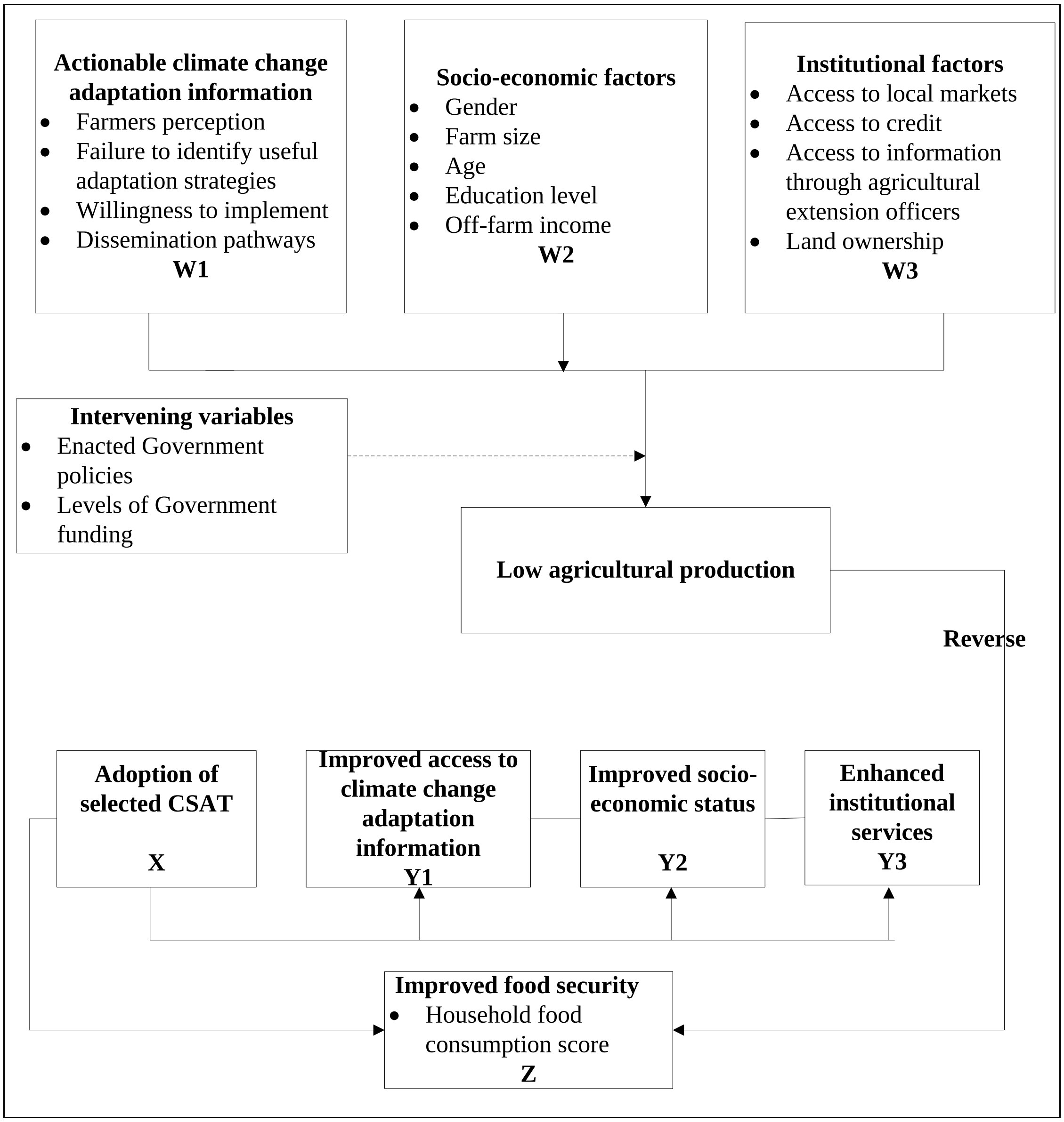

Figure 2.1: Conceptual Framework

W1, W2, W3 = Independent variables; X = Dependent variable; Y1, Y2, Y3 = Expected Output; Z = Expected Outcome

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the Study Areas

The study was conducted in three Counties in the lower Eastern Kenya namely Machakos, Kitui and Makueni Counties (Figure 3.1). The geographical description of the three Counties is shown in Table 3.1. All the three Counties experience a bimodal rainfall pattern and their main socio-economic activities include crop farming (food and cash crops), livestock keeping (mainly beef and dairy cattle, goats and poultry) and bee keeping. The Counties were selected because of decreasing crops yields, poor agronomic practices, low soil fertility, and increasing food insecurity despite efforts made by KALRO and KMD to disseminate climate change adaptation information over the last three years using different communication pathways (Muema *et al*., 2018; Muita *et al*., 2021).

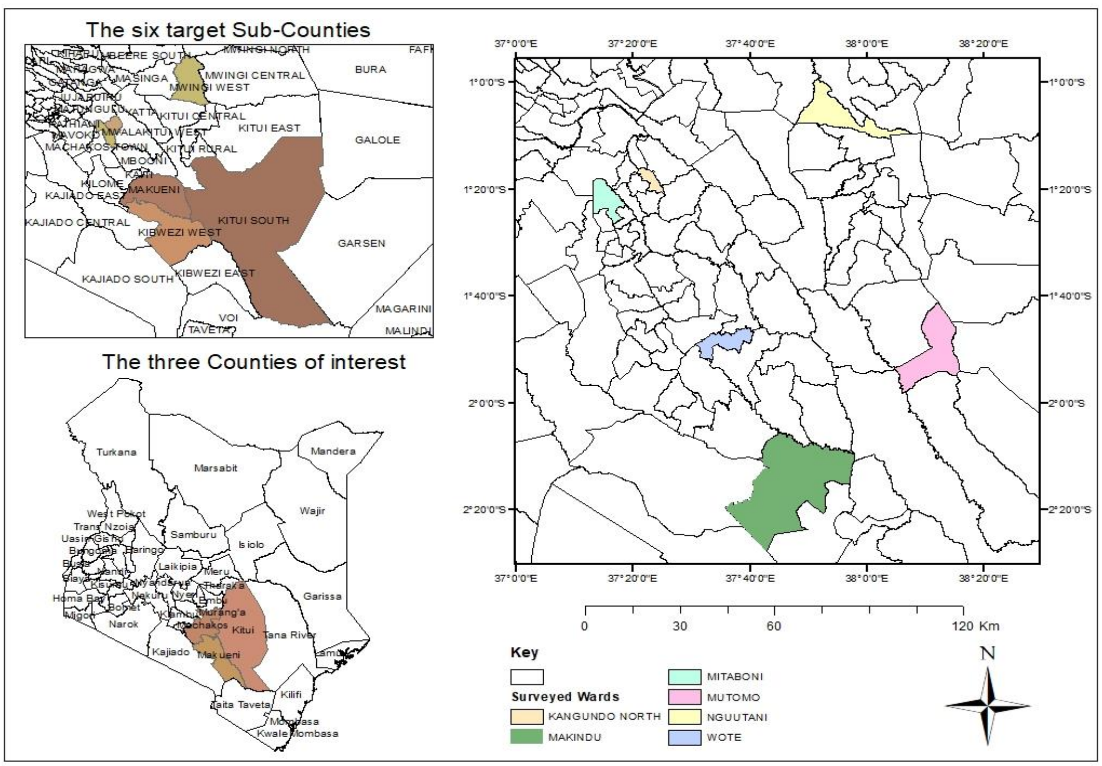

Figure 3.1: Map of the Study Areas

Table 3.1: Geographical Location of the Three Counties

County	Longitude	Latitude	Rainfall (mm)	Temperature (℃)	Area (km^2)	Total population*	Total No. of Households *
Machakos	37° 14.43 E	1° 34.56 S	500 - 1250	18 - 29	6,208.2	1,414,022	402,466
Makueni	37° 37’ 51.99 E	1° 47’11.38 S	250 - 900	20.2 - 35.8	8,008.7	977,015	244,669
Kitui	37° 59' 42.77 E	1°22'30.292 S	200 - 1068	14 - 34	30,496.4	1,130,134	262,942

*Source: KNBS (2019)

3.2 Sampling Design

The study was conducted using a cross sectional survey design. It allowed collection of data at one single point. Also, application of both descriptive and quantitative data analysis techniques was permitted (Kothari, 2004).

3.2.1 Target Population and Sample Size

The target population was 30,885 rural based farming households. Given that the target population was more than 10,000, the sample size was calculated using the Cochran (2007), equation as follows:

$$N = \frac{z^2 pq}{d^2} = \frac{(1.96^2)(0.5)(1-0.5)}{(0.05)^2} = 384 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots 1$$

Where; N= desired sample size, Z= standard normal deviate at 95% confidence level, p= percentage picking a choice, q= 1-p (proportion of population with measuring the characteristic) and d= allowable error.

3.2.2 Sampling Procedure

In selecting respondents, multi-stage random sampling procedure was employed. The first step involved random selection of two sub-counties in each of the three target counties (Table 3.2). In stage two, two wards were randomly selected from the each of the sub-Counties. The third stage involved random selection of 384 households in a proportionate to size manner from a total population of 153,247 small scale households in randomly selected Wards.

Table 3.2: Distribution of Population in the Three Counties

County	Sub-County	No. of HH*	Ward	No. of HH**	Sampled respondents
Machakos	Kathiani	28,730	Mitaboni	7,182	89
	Kangundo	26,142	Kangundo North	6,536	81
Makueni	Kibwezi West	21,756	Makindu	3,626	45
	Makueni	34,479	Wote	4,926	61
Kitui	Kitui South	23,044	Mutomo	3,841	49
	Mwingi West	19,096	Nguutani	4,774	59
Total		153,247		30,885	384

*Source, KNBS (2019); **Source, Ward administrators' list which also formed the sampling frame.

3.3 Data Collection Procedure

Primary data was collected using semi-structured questionnaire designed in an Open Data Kit (ODK) application. ODK was adopted because of its efficiency in data collection, and easy conversion of data to an excel file when downloaded from the server. The questionnaire was pretested and necessary modifications were made before being administered to the selected 384 respondents to solicit information on various climate information pathways, socio-economic and institutional factors that promoted adoption of specific CSA technologies and overall achievement of food security.

3.4 Preliminary Tests

Prior to carrying out the final test, all the hypothesized explanatory variables were tested for multicollinearity. In most cases, multicollinearity problems may arise due to a linear relationship which may result to regression coefficients having wrong signs, smaller t-ratios and high R-square value. As a result, accurate estimation of each variable on the dependent variable becomes difficult (Gujarati, 2004; Woodridge, 2001). In the study, the variance inflation factor (VIF) technique was used and found to be less than 10 (1.16 - 2.21), indicating there were no multicollinearity problems. Further, Hausman test was done to check for the independence of irrelevant alternatives (IIA). According to Hausman and Mc-Fadden (1984), the IIA requirement is that the relative probability of two selected options are not affected by the twenty-six alternatives which are either introduced or removed. IIA premise in this case failed to reject the null hypothesis, indicating MNL is an appropriate model.

3.5 Data Analysis

Descriptive statistics (percentages and frequencies) were used in analysis and presentation of quantitative categorical data using Statistical Package for Social Sciences (SPSS) version 23 and STATA version 13. Multinomial logistic (MNL) regression model, Multivariate Probit (MVP) model and Food Consumption Score (FCS) were then applied to analyze the influence of information pathways, socio-economic and institutional factors influencing adoption of selected CSA technologies, and effects of CSA adoption on food security, respectively.

3.5.1 Climate Change Adaptation Information and CSA Technologies

In analyzing the factors influencing individual farming households adoption of CSA technologies, the MNL regression framework was adopted to enable modeling of perceptions and characterizing small scale farmers depending on the type of technology used (Alem *et al*., 2016). The dependent and independent variables were adoption of selected CSA technologies, and climate information channels, respectively. The model was given as follows;

$$P(y = j / x) = \frac{\exp(xB_j)}{\left[1+\sum_{h=1}^{j} \exp(x\beta_h), j=1 \ldots\ldots J\right]} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \; 2$$

Where; P is probability, y is a random variable taking on the values $\{1, 2, \ldots, J\}$ for a positive integer J, and x denotes a set of conditioning variables. x is a $1 \times K$ vector with first element unity and B_j is a $K \times 1$ vector with $j = 2, \ldots, J$.

3.5.2 Socio-economic and Institutional Factors Influencing Adoption of CSA Technologies

To investigate the socio-economic and institutional factors influencing adoption of selected CSA technologies, MVP model was adopted. This model recognizes correlation in the choice to adopt several adaptation strategies simultaneously. Moreover, the error term correlations may positively (complementarity) or negatively (substitutability) influence decision to adopt a particular CSA technology (Bedeke *et al*. 2019; Ndiritu *et al*., 2014). The dependent variable was adoption of multiple CSA technologies, while the independent variables were the socioeconomic and institutional factors. The algebraic representation of the model was as follows;

$$y_{ijm}^{*} = X_{ijm}\,\beta_m + \varepsilon_{ijm} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots 3$$

Where (y_{ijm}^{*}) =level of expected benefit, (i) = household id, (m) =type of adaptation strategy, (X_{ijm}) =vector of explanatory variables, (β_m) =vector of unknown parameters and (ε_{ijm}) = normally distributed error terms.

3.5.3 Adoption of Selected CSA Technologies on Food Security

On the aspect of food security, the main focus was on the quantity and quality of food consumed on a weekly basis. To determine the effects of selected CSA technologies on food security, Food Consumption Score (FCS) was used. It comprises of three food consumption groups: poor (0 - 28), borderline (28.1 - 42), and acceptable (> 42). In the study, different food intake questions were used to acquire statistics related to household consumption behavior in Machakos, Makueni and Kitui Counties. The household head was questioned about the frequency of consumption of different food items during the last seven days.

Based on the formula proposed in “emergency food security assessment handbook”, FCS was then estimated by multiplying the frequency of foods consumed within seven days with the weighting of each group (WFP, 2009). To reflect nutritional density, specific weights assigned to each of the food groups were main staples 2, pulse 3, vegetables 1, fruit 1, meat and or fish 4, milk 4, sugar 0.5, oil 0.5, and condiments 0. The formula was expressed as follows:

$$FCS = a1 \times f\ (main\ staples) + a2 \times f\ (pulse) + a3 \times f\ (vegetables) + a4 \times f\ (fruit) + a5 \times f\ (meat\ and\ or\ fish) + a6 \times f\ (milk) + a7 \times f\ (sugar) + a8 \times f\ (oil) + a9 \times f\ (condiments) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

Where: FCS =Food Consumption Score; f=frequency (number of days for which each given food group was consumed during the past week); a= weighted value representing the nutritional value of selected food groups.

3.6 Operationalization of Variables

Table 3.3 displays variables used in the study. The positive (+) and (-) sign illustrates a positive and negative effect, respectively.

Table 3.3: Operationalization of Variables

Variable	Description	Measurement	Expected Sign
Climate change adaptation information	Dissemination pathways used	1=Radio, 2=Television, 3=Mobile phone, 4=Agricultural extension agents, 5=Local administrators, 6=Neighbors and friends	+/-
Occurrence of climate change	Aware of climate change	1=yes , 0=no	+/-
Farm Size	Land size	Number of hectares	+
Gender	Gender of respondent	1=male, 0=female	+/-
Age	Age in years	Continuous	+/-
Education	Highest level of education attained	1=None, 2=Primary 3=Secondary 4= College, 5=University	+
Off farm income	Participation in off-farm employment	1=yes , 0=no	+/-
Access to local market	Whether household access markets	1=yes , 0=no	+
Access to credit facilities	Whether household obtain credit	1=yes , 0=no	+
Access to agricultural extension officers	Whether household access extension services	1=yes , 0=no	+/-
Land ownership	Land tenure category	1=own, 2=rented, 3=inherited 4=communal, 5= own plus rent, 6=own plus inherited, 7=own plus communal	+
Food security	Food security status of the household	Food consumption score	

CHAPTER FOUR

RESULTS

4.1 Overview

In this chapter, results are presented and discussed in four sections; socio demographic characteristics of household heads (4.2), climate change adaptation information pathways and their influence on adoption of selected climate smart technologies (4.3), socio-economic and institutional factors influencing adoption of climate smart technologies (4.4), and effects of selected climate smart technologies adoption on food security (4.5).

4.2 Sociodemographic Characteristics of Household Heads

Table 4.1 illustrates the demographic characteristics of households in Machakos, Makueni and Kitui Counties. In all the three Counties, majority of the respondents (54.2%) were male, implying that male farmers in the study areas dominate farming. More than one third (35.7%) of the respondents were in the 36-50 year age bracket indicating that elderly people were involved in farming more as compared to the youths who engage in other off-farm activities. Moreover, 83.3% of the respondents were married and this could be helpful in planning when and which technologies to adopt on-farm.

On the aspect of household head education level, 53.3% of the respondents had attained primary education, meaning that a farmer is empowered to make decisions on appropriate farming methods and technologies to adopt. Additionally, most of the respondents (64.2%) came from families with three to six members, which is an indicator of limited family labor and was expected to slow down adoption of CSA technologies. Further, majority of the farm sizes owned were between one to four hectares (30.7%), inferring more room for CSA technologies adoption on-farm.

Table 4.1: Sociodemographic Characteristics

Demographic factor	County							
	Machakos		Makueni		Kitui		Total	
	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent
Gender								
Male	89	23.2	49	12.8	70	18.2	208	54.2
Female	82	21.4	46	12.0	48	12.5	176	45.8
Age Bracket (Years)								
18-35	35	9.1	17	4.4	25	6.5	77	20.0
36-50	60	15.6	33	8.6	44	11.4	137	35.7
51-60	30	7.8	25	6.5	19	4.9	74	19.3
Above 60	46	12.0	20	5.2	30	7.8	96	25.0
Marital status								
Single	23	6.0	9	2.3	15	3.9	47	12.2
Married	138	35.9	83	23.2	99	25.6	320	83.3
Divorced	3	0.8	2	0.5	1	0.3	6	1.6
Separated	7	1.8	1	0.3	3	0.8	11	2.9
Education level								
Non-formal	12	3.1	6	1.6	15	3.9	33	8.6
Primary	91	23.7	43	11.2	68	17.7	205	53.3
Secondary	50	13.0	36	10.2	28	7.3	114	29.7
College	15	3.9	7	1.8	4	1.0	26	6.8
University	3	0.8	3	0.9	0	0.0	6	1.6
Household size (No.)								
Up to 2	41	10.7	26	6.8	17	4.4	84	21.9
3-6	112	29.2	59	15.4	76	19.8	247	64.2
7-10	17	4.4	8	2.1	23	6.0	48	12.5
11-14	0	0.0	2	0.5	0	0.0	2	0.5
Above 14	1	0.3	0	0.0	2	0.5	3	0.8
Farm size (hectares)								
Less than 1	51	13.3	9	2.3	9	2.3	69	18.0
1-4	57	14.8	25	6.5	36	9.4	118	30.7
5-9	34	8.8	22	5.7	33	8.6	89	23.2
10-14	15	3.9	17	4.4	21	5.5	53	13.8
Above 14	14	3.6	22	5.7	19	4.9	55	14.3

4.3 Climate Change Adaptation Information on Adoption of CSA Technologies

4.3.1 Perception on Climate Variability and Change

The study aimed at determining the view on the observations regarding climate change among the small scale farmers in Kitui, Makueni and Machakos Counties. It was noted that in all the three Counties, majority of the respondents (97.4%) observed climatic variations in their respective areas over the farming period while 2.6% of the respondents did not observe any climatic variations (Table 4.2). This shows that the farmers in the study areas are keen on climate change variations due to the direct impact it has on their farming enterprises, incomes and livelihoods.

Table 4.2: Awareness on Climate Variability and Change

Response	Machakos		Makueni		Kitui		Total	
	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent
Yes	158	97.6	92	95.8	124	97.6	374	97.4
No	3	2.4	4	4.2	3	2.4	10	2.6

4.3.2 Observed Climate Changes Over the Last Five Years

The farmers were asked to identify the major climatic events affecting their farming, more so with regard to the adoption of climate smart agriculture technologies. The multiple responses in Table 4.3 revealed that the areas experienced early rains 93.2%, followed by high temperatures (47.1%), heavy cloudy periods (25.3%) and long rainfall (24.2%). On the other hand, 14.3% and 13.0% reported to have observed excessive drought conditions and low temperatures, respectively.

Table 4.3: Response on Major Climatic Events

Major Climatic event	Response	Machakos		Makueni		Kitui		Total	
		Freq.*	%	Freq.*	%	Freq.*	%	Freq.*	%
Early rains	Yes	149	92.5	94	97.9	115	90.6	358	93.2
	No	12	7.5	2	2.1	12	9.4	26	6.8
Long rainfall	Yes	16	9.9	28	29.2	49	38.6	93	24.2
	No	145	90.1	68	70.8	78	61.4	291	75.8
High temperatures	Yes	68	42.2	55	57.3	58	45.7	181	47.1
	No	93	57.8	41	42.7	69	54.3	203	52.9
Low temperatures	Yes	13	8.1	13	13.5	24	18.9	50	13.0
	No	148	91.9	83	86.5	103	81.1	334	87.0
Excessive drought	Yes	18	11.2	14	14.6	23	18.1	55	14.3
	No	143	88.8	82	85.4	104	81.9	329	85.7
Excessive cloudy periods	Yes	47	29.2	12	12.5	38	29.9	97	25.3
	No	114	70.8	84	87.5	89	70.1	287	74.7

*multiple responses

4.3.3 Farmers Awareness of Climate Smart Agricultural Practices

The study sought to find out whether the farmers in the three Counties were aware of the climate smart practices available for adoption in their areas. The results showed that in all the three Counties, 93.2% of the interviewees were aware of the practices available for adoption in their areas while 6.8% denied being aware of the same (Table 4.4). This implies that a significant portion of the farmers were aware of many CSA technologies and practices, hence the proponents of the practices. This also means they are practicing the same or are aware of farmers in the area who have adopted these climate smart practices.

Table 4.4: Farmers Awareness of Climate Smart Practices

Response	Machakos		Makueni		Kitui		Total	
	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent
Yes	148	91.9	96	100	114	89.8	358	93.2
No	13	8.1	0	0	13	10.2	26	6.8

4.3.4 Sources of Climate Change Adaptation Information

The study established that farmers interviewed across the three Counties received the climate change adaptation information through the radio (37.3%), followed by neighbors and friends (24.3), extension agents (14.0%), mobile phones (9.0%), television (8.9%) and from local administrators (6.0%) (Table 4.5). It was observed that the combined digital media (radio, TV and mobile phones) at 55.2% had greatly contributed to farmers receiving most of the agro-information as compared to the traditional channels of person-to-person.

Table 4.5: Sources of Climate Change Adaptation Information

Information channel	Response	Machakos		Makueni		Kitui		Total	
		Freq.*	%	Freq.*	%	Freq.*	%	Freq.*	%
Radio	Yes	143	88.8	85	88.5	124	97.6	352	37.3
	No	18	11.2	11	11.5	3	2.4	32	62.7
Television	Yes	48	29.8	16	16.7	20	15.7	84	8.9
	No	113	70.2	80	83.3	107	84.3	300	91.1
Mobile phone	Yes	33	20.5	27	28.1	25	19.7	85	9.0
	No	128	79.5	69	71.9	102	80.3	299	91.0
Extension agents	Yes	50	31.1	52	54.2	30	23.6	132	14.0
	No	111	68.9	44	45.8	97	76.4	252	86.0
Local administrators	Yes	24	14.9	23	24.0	10	7.9	57	6.0
	No	137	85.1	73	76.0	117	92.1	127	94.0
Neighbors and friends	Yes	88	54.7	53	55.2	88	69.3	229	24.3
	No	73	45.3	43	44.8	39	30.7	155	75.7

*multiple responses

4.3.5 Main CSA Technologies Adopted by Smallholder Farmers

The most preferred CSA technology among the Counties were mixed farming (88.3%), intercropping (63.5) and crop rotation (56.8%) (Table 4.6). Preference was higher for Makueni County for the first two technologies followed by Kitui then Machakos Counties. The others were agroforestry (48.2%) and conservation agriculture (45.1%). The least preferred technologies were water harvesting and crop diversification at 83.1 and 62.2%, respectively. The overall results show the level of adoption of the technologies was 50.9%

and 49.1% indicate non-adoption, indicating generally about half of the practices have been accepted. On the hand, 55.7, 52.7 and 43.5% of the technologies (singly or in combination) were adopted in Machakos, Makueni and Kitui Counties, respectively. Apparently, distance from the international Nairobi-Mombasa highway influenced adoption of the practices among the Lower Eastern Kenya Counties. This indirectly implies that urbanization and cosmopolitan status of an area influences uptake of agricultural technologies due to ease of information access and coping strategies in the light of climate change and increasing unemployment status. This shows that a farmer's choice for the climate smart practice(s) to adopt may be influenced by other factors such as convenience or ease of adoption, performance by early adopters or socio-economic considerations. This information was gathered during the one-to-one discussion with the farmers while in the field collecting data.

Table 4.6: Main CSA Technologies Adopted in the Three Counties

CSA technology	Response	Machakos		Makueni		Kitui		Total	
		Freq.*	%	Freq.*	%	Freq.*	%	Freq.*	%
Mixed farming	Yes	140	87.0	87	90.6	112	88.2	339	88.3
	No	21	13.0	9	9.4	15	11.8	45	11.7
Intercropping	Yes	103	64.0	63	65.6	78	61.4	244	63.5
	No	58	36.0	33	34.4	49	38.6	140	36.5
Crop rotation	Yes	109	67.7	55	57.3	54	42.5	218	56.8
	No	52	32.3	41	42.7	73	57.5	166	43.2
Crop diversification	Yes	80	49.7	45	46.9	20	15.7	145	37.8
	No	81	50.3	51	53.1	107	84.3	239	62.2
Conservation agriculture	Yes	86	53.4	40	41.7	47	37.0	173	45.1
	No	75	46.6	56	58.3	80	63.0	211	54.9
Water harvesting	Yes	29	18.0	17	17.7	19	15.0	65	16.9
	No	132	82.0	79	82.3	108	85.0	319	83.1
Agroforestry	Yes	81	50.3	47	49.0	57	44.9	185	48.2
	No	80	49.7	49	51.0	70	55.1	199	51.8
Overall	Yes	638	55.7	354	52.7	387	43.5	1369	50.9
	No	499	44.3	318	47.3	502	56.5	1319	49.1

*multiple responses

4.3.6 Adopters of Climate Smart Agriculture Technologies in the Three Counties

The study sought to determine whether most of the farmers were using the technologies in their farms. The results illustrate that 52.6% of the farmers across the three Counties had not adopted any of the technologies while 47.4% had adopted some of these technologies in their farms (Table 4.7). This indicates that despite farmers receiving the information from various channels, more than half of them have not adopted or implemented CSA technologies in their farms. This could be attributed to lack of trust and knowledge among the farmers in lower Eastern Kenya.

Table 4.7: Adoption of Climate Smart Agriculture Technologies

Response	Machakos		Makueni		Kitui		Total	
	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent
Yes	75	46.6	42	43.8	65	51.2	182	47.4
No	86	53.4	54	56.3	62	48.8	202	52.6

4.3.7 Factors Influencing Farmers' Adoption of CSA Technologies

The results of Multinomial logistic regression model (MNL) obtained and presented in Table 4.8 indicate that the adaptation technologies were grouped into seven categories since households used more than one technology. Mixed farming had the highest adoption level, thus used as a reference category.

Table 4.8: Multinomial Logistic Regression Analysis

Variable	Intercropping	Crop rotation	Conservation agriculture	Agroforestry	Crop diversification	Water harvesting
	βCoef (P-value)	βCoef (P-value)	βCoef (P-value)	βCoef (P-value)	βCoef (P-value)	βCoef (P-value)
The effect of socio-economic characteristics and information sources on farmers' choice of adaptation technologies						
Gender	0.367	1.431	0.223	1.207	0.353	0.241
	(0.320)	(0.000)***	(0.555)	(0.009)***	(0.316)	(0.537)
Age	-0.676	-0.121	-0.430	-1.539	0.226	-0.062
	(0.222)	(0.461)	(0.445)	(0.065)**	(0.068)*	(0.912)
Education level	0.054	1.223	0.024	0.018	1.046	-0.010
	(0.503)	(0.003)**	(0.943)	(0.092)*	(0.065)*	(0.922)
Household size	-0.010	0.371	0.540	-0.204	1.416	0.898
	(0.982)	(0.424)	(0.253)	(0.731)	(0.020)**	(0.092)*
Farm size	0.290	0.284	0.368	0.221	-1.111	0.089
	(0.005)***	(0.040)**	(0.245)	(0.508)	(0.629)	(0.194)
TV	0.671	-0.024	0.896	2.705	0.605	0.179
	(0.173)	(0.965)	(0.064)*	(0.000)***	(0.220)	(0.762)
Radio	-0.304	-0.148	-0.275	0.149	-1.012	1.297
	(0.651)	(0.827)	(0.681)	(0.874)	(0.082)**	(0.236)
Mobile phone	0.349	-0.531	-0.628	-2.128	-0.212	-2.096
	(0.392)	(0.252)	(0.206)	(0.009)***	(0.607)	(0.008)***
Extension Agents	0.806	-0.046	-0.020	-0.631	1.433	0.189
	(0.042)**	(0.913)	(0.965)	(0.294)	(0.000)***	(0.672)
Local administrator	0.396	2.328	-0.728	1.969	2.071	0.845
	(0.552)	(0.000)***	(0.513)	(0.011)**	(0.000)***	(0.232)
Neighbors and friends	-0.394	-0.769	-0.257	-1.390	-1.511	0.027
	(0.324)	(0.053)**	(0.519)	(0.002)***	(0.000)***	(0.949)

Reference category = Mixed farming, Number of observations=384, Asterisks ***, ** and * signify significance at 1%, 5% and 10% level. LR chi^2 =203.584, Prob >X^2= 0.000, Pseudo R^2 = 0.556, Log-likelihood =-575.165.

The results reveal that gender of the household head statistically and positively influenced adoption of crop rotation and agroforestry at 1%. This indicates that a male-headed household increases the likelihood of adopting crop rotation and agroforestry by a factor of 1.431 and 1.207, respectively. Age of the household head significantly reduced ability of smallholders to adopt agroforestry at 5%. This implies that as the age of the household head increased by one year, chances of using agroforestry reduced by a factor of 1.539. The unwillingness to adopt the technology increases with age since the benefits of trees in agroforestry take long to realize and the elderly farmers may find it unnecessary to invest in tree planting.

Increase in education level positively and significantly affected farmers' decision to adopt crop rotation, agroforestry and crop diversification by 0.3%. 9.2% and 6.5%, respectively. Household size had a significant and positive influence on adoption of crop diversification at 5%, implying that a unit increase in the family members increased the possibility of adopting the aforementioned technology by a factor of 1.416. On the other hand, farm size significantly and positively affected adoption of intercropping and crop rotation at 1% and 5% respectively. This infers that farmers with adequate land sizes are more likely to take up intercropping and crop rotation than those with small land sizes.

Use of television as a source of information positively influenced adoption of conservation agroforestry by a factor of 2.705. This shows that farmers who own television sets are able to access more agricultural information on agroforestry than those without. Moreover, accessibility to radio had a significant negative influence on the adoption of crop diversification by 8.2%. This suggests that despite many smallholder farmers owning a radio, majority were not fully exposed to crop diversification programmes. Additionally, the timing for the related programmes with respect to farmers' schedule of activities and the language of communication could have attributed to low adoption of crop diversification.

Ownership of a mobile phone negatively influenced adoption of agroforestry and water harvesting at 0.9% and 0.8%, respectively. The low uptake among the farmers in the study area could have resulted from few farmers using it to access agricultural information or the call charges involved in accessing the information. Additionally, access to agricultural extension services positively influenced use of intercropping and crop diversification by a factor of 0.806 and 1.433, respectively. The implication could be that frequent interactions between farmers and extension agents contributes to increased awareness of agricultural technologies, thus motivating farmers to try out the technologies on-farm. Equally, most of the on-farm field demonstrations are managed by extension providers, hence enhancing learning and adoption these technologies.

Access to local administrators had a significant and positive influence on adoption of crop rotation, agroforestry and crop diversification by a factor of 2.328, 1.969 and 2.071, respectively. This means that easy access of smallholder farmers to their chief(s) and village elders in the sampled regions promoted access of appropriate knowledge on the aforementioned technologies. This would be due to the general thrust by rural folk on their leader who often guides opinion on matters affecting them. The traditional concept of coercion by public leaders promoting certain government agenda like better farming methods may have given rise to such high levels of adopting the CSA technologies being promoted in the respective areas. However, information obtained from neighbours and friends had a significant negative effect on adoption of crop rotation, agro-forestry and crop diversification by a factor of 0.257, 1.390 and 1.511, respectively. This could be due to other farmers' not having adequate and reliable knowledge on proper use of these technologies in their farms or, as they say, familiarity brings contempt.

4.4 Socio-economic and Institutional Factors on Adoption of CSA Technologies

4.4.1 Main Farming Systems

The study revealed that Mixed farming (94.01%) is embraced by most farmers within the regions (Table 4.9). Only 5.47 and 0.52% of the farmers engaged in crop production and livestock rearing, respectively. Mixed farming may be used by the smallholder farmers as a way of diversifying sources of income and guarding against adverse effects of climate change, thereby improving their resilience. The practice also allows for diversified source(s) of food for the households.

Table 4.9: Main Farming System

Main farming system	Frequency	Percent (%)
Crop production only	21	5.47
Livestock rearing only	2	0.52
Mixed farming	361	94.01

4.4.2 Number of Years Spent in Farming

The findings in Table 4.10 indicate that close to two thirds (64.32%) of the farmers in the study locations have been farming for more than fifteen years, followed by 14.84% with a farming experience of between five to ten years. The rest at 11.20 and 9.64% had been in the farming business for less than five and between eleven to fifteen years, respectively. This underscore the fact that rural households are mainly dependent on farming as the main enterprise. Farming for many years is beneficial to a farmer as it increases the probability of adopting best agricultural practices that enhance productivity per unit farmland.

Table 4.10: Period of farming

Period (Years)	Frequency	Percent (%)
Less than 5 years	43	11.20
5-10 years	57	14.84
11-15 years	37	9.64
More than 15 years	247	64.32

4.4.3 Crops Grown in Lower Eastern Kenya

The lower Eastern Kenya lies within the Arid and Semi-arid regions, thus supporting a wide variety of drought tolerant crops. From the findings it is worth noting that many of the respondents (23.69%) grow maize (Figure 4.1). Planting of cow pea (19.50%), pigeon pea (18.34%), beans (16.35%), and green grams (14.05%) has also been embraced due to their high drought resistance capabilities. Crops which are not popularly grown comprise of sorghum (5.27%) and millet (2.80%). This demonstrates that farmers within the lower Eastern Counties prefer growing staple food crops like maize and legumes to guarantee food security at all times. The taste of food and ease of preparing it using maize would be another reason for its preference among farmers over sorghum and millet.

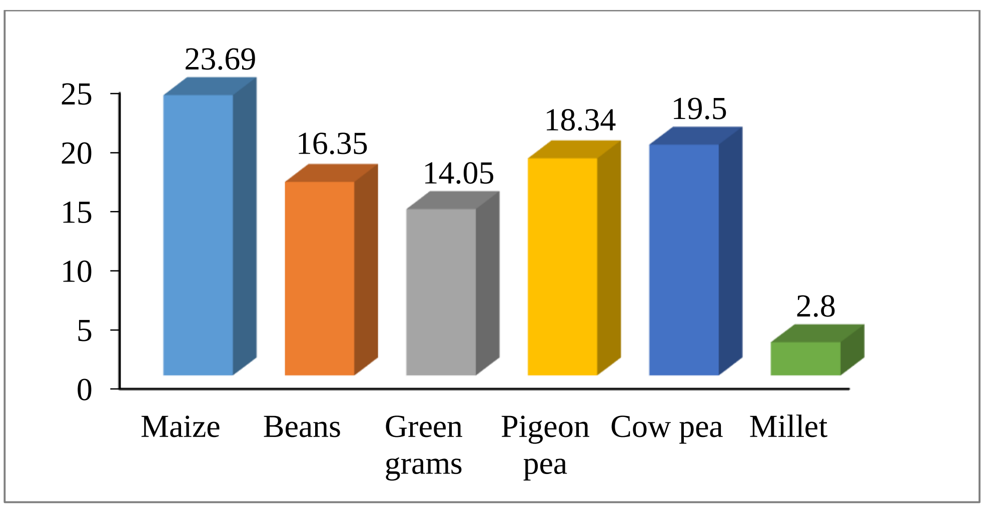

Figure 4.1: Drought Resistant Crops Grown in Lower Eastern Kenya

4.4.4 Average Annual Income Generated from Farming Activities

Farm income plays a sufficient role in adoption of agricultural technologies. The results in Table 4.11 indicate that majority of the farmers (32.55%) earned less than Kes 10,000 while 22.66% earned between Kes 11,000 and 20,000 annually. The others constituting of 17.45, 15.63 and 7.03% had annual earnings ranging between Kes 21,000 to 30,000, and Kes 31,000 to 40,000, respectively. Only 11.72% earned more than Kes 40,000. Adoption of agricultural technologies is high among farmers who are financially stable because they can pay to access information which minimizes risks and facilitates a longer-term planning.

Table 4.11: Annual Farmers Income in Lower Eastern Kenya

Income (Kes)	Frequency	Percent (%)
0-10000	125	32.55
11000-20000	87	22.66
21000-30000	67	17.45
31000-40000	60	15.63
>40000	45	11.72

4.4.5 Type of Land Used for Agricultural Activities

The study indicated that 24.00% of the respondents cultivated farms obtained through inheritance, 20.47% on purchased plots and 14.80% on rented land (Figure 4.2). Moreover, 12.85%, 10.41% and 9.68% of the farmers did farming on both own and inherited plots, communally owned plots, and own plus rented plots, respectively. The rest (7.85%) grew crops on both communal and own plots. It may be presumed that households owning land are more likely to easily adopt modern agricultural technologies since they do not run the risk of expiring land rental in the face of climate change and food scarcity.

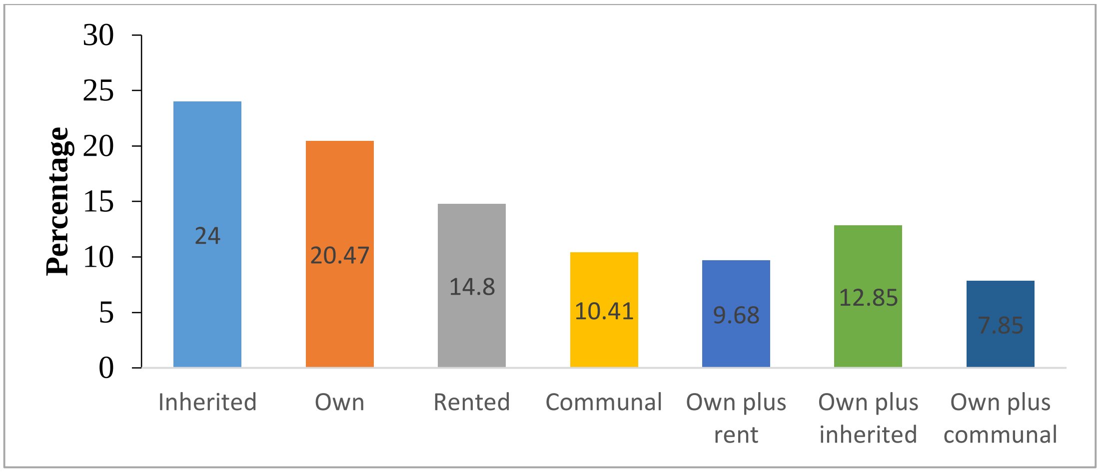

Figure 4.2: Land Owned by Smallholder Farmers

4.4.6 Access to Loan and Credit Facilities

Accessibility to loans and credit facilitates greatly adoption of various technologies. The results illustrate that 76.3% of the farmers in all Counties had no access to loan and credit facilities while 23.7% of the respondent's accessed credit facilities (Table 4.12). Credit provision has the advantage to ease financial constraints to meet their need of changing from traditional to modern practices that suit the forecasted climate change.

Table 4.12: Accessibility to Loan and Credit Facilities

Response	Machakos		Makueni		Kitui		Total	
	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent
Yes	36	22.4	29	30.2	26	20.5	91	23.7
No	125	77.6	67	69.8	101	79.5	293	76.3

4.4.7 Sources of Loans and Credit

The results in Table 4.13 show that respondents who had access to loans and credit facilities reported to mostly obtain the money through table banking (25.50%), microfinance organizations (23.40%), farmers' cooperatives societies (21.97%), and banks (20.35%). Other sources included remittances (7.73%) and own businesses (1.05%). This shows that the main sources of loans and credit for the farmers are formalized institutions that guarantee financial security and reliability. The empowered farmers can then invest in sourcing information on adoption of appropriate CSA practices in their farms.

Table 4.13: Loan and Credit Sources

Loan and credit source	Frequency	Percent (%)
Farmers' cooperative organizations	84.38	21.97
Microfinance organizations	89.84	23.40
Banks	78.13	20.35
Table banking	97.92	25.50
Remittances	29.67	7.73
Own business	4.06	1.05

4.4.8 Constraints Preventing Access to Loan and Credit Facilities

Majority of the respondents who did not access loans and credit facilities indicated high interest rate, lack of security, and inadequate access to information on credit facilities as their major worry and constituted 25.39, 23.40, and 20.81% of the responses, respectively (Table 4.14). It was also observed that inadequate time (17.13%) and inadequate banking services (13.28%) among the farmers hindered borrowing of loans. These barriers to ease of access of loans and credit facilities would have a negative impact on farmers' ability to adopt CSA technologies appropriate for their areas, hence remain struggling with traditional resilience approaches that give little benefit to their worth effort.

Table 4.14: Loan and Credit Constraints

Constraint	Frequency	Percent (%)
High interest rate	97.48	25.39
Lack of security	89.84	23.40
Inadequate access to information on credit facilities	79.90	20.81
Inadequate banking services	50.99	13.28
Inadequate time	65.79	17.13

4.4.9 Constraints Associated with Access to Agricultural Inputs

Purchasing of agricultural inputs is challenging, especially for farmers in rural areas. The study revealed that limited funds (29.69%) greatly hindered accessibility (Table 4.15). Moreover, high cost (27.86%), long distance to the market (20.57%), poor roads (13.54%) and inadequate information (8.33%) were some of the other main challenges experienced. This implies that the will of farmers to expand farm production cannot be easily realized in the face of these constraints. There is need for the government and other stakeholders in the sector to provide farm inputs like seeds, fertilizers and agrochemicals at subsidized prices so as to boost farmers' efforts.

Table 4.15: Constraints to Access of Agricultural Inputs

Constraints	Frequency (f)	Percent (%)
Long distance to the market/source	79	20.57
Poor roads	52	13.54
Limited funds	114	29.69
High cost	107	27.86
Inadequate information on availability and use	32	8.33

4.4.10 Access to Extension Services

Extension services are important sources of information on climate, agronomic practices, marketing of farm produce, emerging technologies, crop production, among other services. The results indicated 59.4% of the respondents in the three Counties did not have adequate access to extension services while the rest did receive (Table 4.16). This shows that farmers within Lower Eastern region of Kenya have not fully benefitted from agricultural extension services necessary to assist in making comparative decision on which technologies to choose so as to cope better with changes in climate and increasing food demand.

Table 4.16: Farmers Access to Extension Services

Response	Machakos		Makueni		Kitui		Total	
	Freq.	**Percent**	**Freq.**	**Percent**	**Freq.**	**Percent**	**Freq.**	**Percent**
Yes	65	40.4	54	56.3	37	29.1	156	40.6
No	96	59.6	42	43.8	90	70.9	228	59.4

4.4.11 Extension Training Methods Used by Agricultural Officers

The methods used to disseminate agricultural techniques greatly influence its uptake rate. It was noted that the widely used extension techniques were farmer visits to ATCs (24.51%) and farm visits (22.71%) from NGO extension officers (Table 4.17). Other extension training methods used in delivering information to farmers in lower Eastern Kenya were farmer field schools (17.66%), field demonstrations (15.38%), and internet delivery (6.99%). Training farmers is important as it instills better farming techniques that will enhance farm productivity.

Table 4.17: Extension Training Methods and Techniques

Method used	Frequency	Percent (%)
Farmers’ trainings and visits	87.22	22.71
Agricultural training centers (ATCs)	94.10	24.51
Field demonstrations	59.05	15.38
Farmers field schools (FFS)	67.83	17.66
Internet delivery	26.85	6.99
Telephone communications	48.95	12.75

4.4.12 Challenges Hindering Access to Extension Services

Although access to extension officers improves farmers access to climate information and agricultural technologies, respondents reported to have faced several challenges. The findings revealed that more than 90% of the farmers did not receive adequate information about the extension services (Table 4.18). Other challenges reported included high charges for extension services (22.24%), low financial resources (20.54%), fewer extension officers (17.91%) and research centers being located too far (15.36%). It is evident that less contact with agricultural extension can immensely hinder farmers will to adopt CSA technologies relevant to their areas in case other methods are lacking. Charging for extension service provision would significantly reduce the proportion of farmers in need of the service. The role of NGO's in providing extension services to farmers help boost the government's effort in ensuring rural food security since most residents engage in agriculture.

Table 4.18: Challenges of Accessing Extension Services

Challenge	Frequency	Percent (%)
Low financial resources	78.88	20.54
Inadequate information about extension services	91.96	23.95
Fewer extension officers are available	68.79	17.91
Payment for extension services is expensive	85.42	22.24
Research centers are located too far	58.95	15.36

4.4.13 Determinants of Multiple Climate Change Adaptation Practices

Table 4.19 presents the multivariate probit results on the multiple factors influencing farmers' adoption decision on CSA technologies. The model contained seven dependent variables and ten explanatory variables.

Table 4.19: Multivariate Probit Analysis

Variable	Mixed farming	Intercropping	Crop rotation	Conservation agriculture	Agroforestry	Crop diversification	Water harvesting
	Coef. (Std err)	Coef. (Std err)	Coef. (Std err)	Coef. (Std err)	Coef. (Std err)	Coef. (Std err)	Coef. (Std err)
Socio-economic factors							
Age	-0.192**	-0.314**	0.162***	0.244***	-0.653***	0.313***	0.102***
	(0.161)	(0.286)	(0.216)	(0.052)	(0.182)	(0.002)	(0.001)
Gender	-0.756	-0.603	0.436*	0.158**	-0.329	0.147**	0.034**
	(0.236)	(0.154)	(0.116)	(0.255)	(0.296)	(0.055)	(0.042)
Education level	0.179**	-0.140	0.550	0.165**	0.424	-0.110	0.027
	(0.106)	(0.298)	(0.111)	(0.144)	(0.162)	(0.097)	(0.077)
Household size	-0.420**	0.319***	-0.428**	-0.117**	0.227**	0.307**	0.516**
	(0.227)	(0.101)	(0.218)	(0.195)	(0.210)	(0.011)	(0.009)
Off-farm employment	-0.115	-0.224	-0.319	0.096**	-0.121	-0.256	0.294**
	(0.136)	(0.054)	(0.150)	(0.055)	(0.106)	(0.003)	(0.142)
Farm size	-0.003**	0.192**	0.488	-0.368**	-0.201**	0.225***	0.152***
	(0.016)	(0.085)	(0.112)	(0.015)	(0.165)	(0.215)	(0.164)
Institutional factors							
Distance to nearest market	0.769***	-0.510**	-0.411**	-0.627**	-0.211**	-0.104**	0.301***
	(0.183)	(0.073)	(0.065)	(0.035)	(0.105)	(0.165)	(0.144)
Access to credit facilities	0.262	-0.147	0.302	0.244**	-0.655	0.492**	0.303*
	(0.142)	(0.163)	(0.105)	(0.064)	(0.029)	(0.162)	(0.149)
Agricultural extension access	-0.310*	-0.269	0.351**	0.472**	0.104	-0.140	0.254**
	(0.136)	(0.053)	(0.076)	(0.154)	(0.159)	(0.180)	(0.141)
Land ownership	-0.212*	0.033*	0.343**	-0.132	0.202	0.197***	-0.114*
	(0.134)	(0.084)	(0.012)	(0.151)	(0.178)	(0.150)	(0.139)

Likelihood ratio test of $Rho_{ij} = 0$; Wald X^2 (20) = 148.78; p-value = 0.0000; Number of observations = 384; Log likelihood = -3701.44; ***, ** and * show significance at 1%, 5% and 10% respectively.

Results given in Table 4.19 illustrate that age of the farmer significantly and negatively reduced adoption of mixed farming, intercropping and agroforestry at 10% and 1% respectively, while it increased adoption of crop rotation, conservation agriculture, crop diversification and water harvesting at 1% respectively. Increased adoption of the aforementioned technologies could be attributed to more knowledge and experience gained by older farmers over time and ability to evaluate technology information unlike younger farmers. Gender of the household was positive and significant in adoption of conservation agriculture, crop diversification and water harvesting at 5% respectively. This illustrates a higher likelihood of male-headed households adopting the above-mentioned technologies as compared to their counterpart female farmers.

Household education increased adoption of mixed farming and conservation agriculture only at 10% confidence level. This means that obtaining relevant information on agricultural technologies increases awareness about the benefits and hence the adoption rates. On the aspect of household size, there was a positive and significant impact on uptake of intercropping, agroforestry, crop diversification, and water harvesting at 1% respectively while low adoption was recorded for mixed farming, crop rotation and conservation agriculture at 1% each. The justification on increased adoption could be availability of necessary labor within large households.

Off-farm employment was positive and significant in adoption of conservation agriculture and water harvesting at 10% respectively. This could mean that having diversified income-generating sources enhances farmers' capacity to adopt and implement improved agricultural technologies. Furthermore, size of farm cultivated negatively and significantly reduced adoption of mixed farming, conservation agriculture and agroforestry at 10% each. However, there was an increased adoption of intercropping at 10%, crop diversification and water harvesting at 1% each. This implies that small land holdings can afford putting up a tree nursery but hardly have enough land for crop diversification and erecting water harvesting structures. On the other hand, owners of large parcels of land can afford to purchase seedlings and subdivide their farms to grow different crops.

Nearest market distance was significant and had a negative relationship with all the technologies except in mixed farming and water harvesting at 1% respectively. The probable reason for the negative relationship is that long distance becomes costly and lessens farmers' ability to supply goods or access them from the markets. High value produce from the mixed farming may not be affected by distance to markets since customers would come for them in the farm, saving the farmers' transportation costs while water harvesting involves structures installed in the farm. Conversely, the positive relationship could signify less opportunity cost in adapting labor-intensive practices among rural households. Furthermore, access to credit facilities increased adoption of conservation agriculture and crop diversification at 10% each. The credit facilities financially empower farmers to participate in cooperative action and try additional investments related to agricultural production.

Agricultural extension contacts are positively correlated with crop rotation, conservation agriculture and water harvesting at 10% each. It is expected that farmers' access to extension agents' increases flow of technical agricultural information. In addition, ownership of title deeds positively increased adoption of crop rotation and crop diversification at 10% and 1%, respectively. The implication is that farmers owning land have the freedom to invest on the CSA practices without the risk of disruption in the course of farming.

4.5 Effects of Climate Smart Agriculture Adoption on Food Security

4.5.1 Consumption of Locally Grown Foods

Table 4.20 demonstrates that most of the households across the three Counties (63.5%) consume locally grown foods such as pigeon pea, cow pea, maize, and green grams on a daily basis while 36.5% consume on a weekly basis. The overdependence on locally grown foods could be due to the poor socio-economic status that has forced most households to rely on a cheaper source of food calories.

Table 4.20: Frequency of Local Foods Consumption

Food consumption frequency	Machakos		Makueni		Kitui		Total	
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Daily	94	58.4	61	63.5	89	70.1	244	63.5
Weekly	67	41.6	35	36.5	38	29.9	140	36.5

4.5.2 Adoption of Climate Smart Agriculture Technologies

Table 4.21 illustrates the number of farmers interviewed and the extent of CSA adoption across the three counties. The extent of using CSA technologies was more evident in Machakos County (24.2%), followed by Kitui, and Makueni Counties at 15.4% and 7.8%, respectively. The higher adoption rates in Machakos could be due to early dissemination of the technologies due to its proximity to urban Nairobi County that provides ready market for most produce. This relates well with observation made in Sec. 4.4.9 on distance to market. With an overall adoption rate of 47.4%, information on CSA technologies is yet to reach majority of the farmers in these regions.

Table 4.21: Rate of CSA Adoption in the Three Counties

County	Sample size	Number of CSA adopters	% using CSA technologies
Machakos	161	93	24.2
Makueni	96	30	7.8
Kitui	127	59	15.4
Total	**384**	**182**	**47.4**

4.5.3 Food Consumption Score

The findings in Table 4.22 reveal that majority of the households in Kitui (73%) had a poor food consumption score as compared to households in Machakos (68.94%) and Makueni (67.71%). About 31% of the households in Makueni and 29.81% in Machakos had a higher borderline FCS as compared to households in Kitui (24%). In addition, 2% of the respondents in Kitui County had an acceptable FCS as compared to 1% of households in Machakos and Makueni. The acceptable and bordeline FCS could be attributed to other County dynamics including the weather, population, land tenure, extension services, access to cooperatives, infrastructure in the focus areas as well as leadership and political influence.

Table 4.22: Percent Household Food Consumption Scores in the Three Counties

Indicator	**Machakos (n=161)**	**Makueni (n =96)**	**Kitui (n =127)**	**All households (n =384)**
0 - 28 (poor)	68.94	67.71	73.23	70.05
28.1 - 42 (borderline)	29.81	31.25	24.41	28.39
> 42 (acceptable)	1.25	1.04	2.36	1.56
Total	**100**	**100**	**100**	**100**

4.5.4 Effects of CSA Adoption on Food Security

The findings in Table 4.23 illustrate the effects of CSA adoption on food consumption scores. In Kitui County, households that adopted mixed farming had a higher poor food consumption profile (73.1%) as compared to households in Machakos and Makueni at 69.3% and 67.8%, respectively. Majority of the households in Makueni (31%) had a borderline food consumption while 2.7% of households in Kitui were within the acceptable profile. Use of intercropping contributed to a higher poor food consumption in Makueni (76.2), while 32% and 1.6% of households in Machakos and Makueni were within the bordeline and acceptable profile, respectively.

Adoption of crop rotation led to majority of households in Kitui (74.1%) having a higher food consumption score. Similarly, households in Machakos (29.4%) and Kitui (3.7%) had a higher borderline and acceptable profile, respectively. Further, households using crop diversification in Kitui had a higher poor food consumption (80%) but those in Makueni (26.7%) and Machakos (1.3%) Counties had a higher borderline and acceptable food consumption scores, respectively.

Table 4.23: Effects of CSA Technologies on Food Security

CSA technology	**Food security indicator**	**Machakos (%)**	**Makueni (%)**	**Kitui (%)**
Mixed farming	Poor	69.3	67.8	73.2
	Borderline	30.0	31.0	24.1
	Acceptable	0.7	1.1	2.7
Intercropping	Poor	67.0	76.2	73.1
	Borderline	32.0	22.2	25.6
	Acceptable	1.0	1.6	1.3
Crop rotation	Poor	68.8	70.9	74.1
	Borderline	29.4	29.1	22.2
	Acceptable	1.8	0	3.7
Crop diversification	Poor	72.5	73.3	80
	Borderline	26.3	26.7	20
	Acceptable	1.3	0	0
Conservation agriculture	Poor	69.8	72.5	68.1
	Borderline	30.2	25.0	27.7
	Acceptable	0	2.5	4.3
Water harvesting	Poor	72.4	64.7	52.6
	Borderline	27.6	35.3	42.1
	Acceptable	0	0	5.3
Agroforestry	Poor	60.5	72.3	71.9
	Borderline	38.3	27.7	24.6
	Acceptable	1.2	0	3.5

Moreover, majority of the households using conservation agriculture in Makueni (72.5%) had a higher poor food consumption score. Households in Machakos and Kitui had a higher borderline and acceptable food consumption scores at 30.2% and 4.3%, respectively. In addition, use of water harvesting led to a higher poor food consumption score in Machakos County (72.4%), higher borderline and acceptable food consumption in Kitui at 42.1% and acceptable 5.3%, respectively. Agroforestry adoption led to a higher poor food consumption in Makueni (72.3%). Machakos and Kitui Counties had a higher borderline and acceptable food consumption scores at 38.3% and 3.5%, respectively.

Generally, crop diversification had the highest poor food consumption in Kitui County at 80%. This means that farmers in these region lack adequate knowledge on proper use of the technology so as to ensure food production throughout the seasons. Water harvesting adoption in Kitui County had the highest borderline profile at 42.1%. The implication could be that most farmers in Kitui have concentrated and invested more in rain water harvesting especially when rainfall is abundant for periods when water is scarce. Moreover, Kitui County had the highest acceptable food consumption due to adoption of water harvesting, implying that farmers in this region use the harvested water to irrigate their farms during the drier seasons thus having food enough food all year round.

CHAPTER FIVE

DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Overview

The chapter summarizes the study objectives, literature review, conclusions, policy implications, and recommendations for future research.

5.2 Discussion

5.2.1 Climate Change Adaptation Information on Adoption of CSA Technologies

The study findings indicated that farmers in the three Counties perceived occurrence of climate change and variability. Majorly, occurrence of early rains and high temperatures affected their farming. This result agrees with Ndung'u *et al*. (2021) who noted that most of the farmers' in semi-arid areas of lower Eastern are greatly vulnerable to climate extremes due to high number of floods, strong winds and droughts. The results also showed that a greater proportion of the farmers are aware of CSA technologies through dissemination channels like the digital media and extension officers. Despite the awareness, most respondents are yet to adopt all the technologies on-farm. This could be attributed to lack of technology trust and technical capacity among the farmers' social status, type of technology, and high cost incurred during uptake (Nyasimi *et al*., 2017).

The findings of Multinomial regression indicated that gender of the household head positively influenced adoption of crop rotation and agroforestry. Male-headed households are in a better position to adopt a new practice, access climate information and agricultural technologies unlike female-headed households as corroborated by Belay *et al*. (2017). Age negatively affected adoption of agroforestry. The implication is that as the age of the household head increased by one year, chances of using agroforestry reduced by 6.5%. Usually, older farmers happen to be more knowledgeable and could have gathered more knowledge and capital through the years but find it unnecessary to invest in long-term ventures such as agroforestry in their sunset years. Totin *et al*. (2018), noted that despite farmers failing to consult external sources, the likelihood of adopting new farming methods was still high. On the other hand, an increase in household head age by one year increased the possibility of farmers adopting crop diversification. This finding agrees with that of Saguye (2017) who noted that low adoption rates among young farmers mainly resulted from longer planning horizons and resistance to change.

Increase in education level increased adoption of crop rotation, agroforestry and crop diversification. Generally, education is believed to improve an individual's reasoning capability as well as increasing awareness of viable technologies to be adopted. The implication is that the likelihood of households with better formal education adopting appropriate climate smart technologies is higher as compared to non-educated households. This finding agrees to earlier empirical evidence showing the positive impacts of education on farmers' decision to take up agricultural technologies (Tokede *et al*., 2020).

Household size positively influenced adoption of crop diversification. According to Gebremariam & Tesfaye (2018), the likely reasons why larger family sizes with many productive household members managed to reduce climate change impacts was due to availability of enough labor force. Conversely, farm size increased adoption of intercropping and crop rotation. This was attributed to availability of adequate land as the necessary resource to facilitate the adoption of these two agricultural technologies. The outcome corroborates the study by Teshome & Baye (2018), who observed a high probability of households with large farm sizes adopting new land management technologies unlike those having small farm sizes.

Use of television as a source of information positively influenced adoption of conservation agroforestry. This suggests that farmers owning television sets are able to access more agricultural programmes on agroforestry than those without. The finding corresponds to Muema *et al*. (2018), who observed that broadcasting agricultural programme through television stations could strongly impact farmers. The results further showed that farmers' accessibility to radio negatively influenced adoption of crop diversification. This suggests that despite many smallholder farmers owning a radio, the farmers were not fully exposed to crop diversification programme. This finding may be explained by the earlier finding by Mtega (2018), who noted that although most farmers in Ondo state Nigeria owned a radio, 90% failed to listen to agricultural programme.

Ownership of a mobile phone negatively influenced adoption of agroforestry and water harvesting at 0.9% and 0.8%, respectively. The low uptake among the farmers in the study area could have resulted from few farmers using it to access agricultural information. The finding is related to a study by Folitse *et al*. (2019), which showed that despite ownership of mobile phones, few farmers subscribed to agricultural related short message service (SMS) and apps, thus negatively impacting rural productivity. Additionally, access to agricultural extension services positively influenced use of intercropping and crop diversification. This result is consistent with that of Urassa & Mvena (2016), who claimed that frequent interactions between farmers and extension agents contributes to increased awareness of agricultural technologies, thus motivating farmers to try out the technologies on-farm.

Access to local administrators increased adoption of crop rotation, agroforestry and crop diversification. This could result from easier access of smallholder farmers to their local administrators like the chief and village elders in the sampled regions. According to Ketema and Kebede (2017), frequent farmer to local administrator's interactions permitted easy access of appropriate agricultural knowledge. On the other hand, information obtained from neighbors and friends adversely affected adoption of crop rotation, agro-forestry and crop diversification. This could be due to other farmers' not having adequate and reliable knowledge on proper use of these technologies in their farms. A study by Mekonnen *et al.* (2018), also identified that having a larger network of neighbors slowed adoption of improved cereal varieties among Ethiopian farmers.

5.2.2 Socio-economic and Institutional Factors on Adoption of CSA Technologies

The results indicate mixed farming as the most embraced system. This could have been facilitated by small tracks of lands used for cultivation. The possible reason could be that smallholder farmers use the CSA technologies together with other crop management practices such as improved seed varieties and timely weeding, that enhance high food production (Makate *et al*., 2019). The finding relates to Ntshangase *et al*. (2018), whereby adoption of no-till conservation agriculture was facilitated by small land sizes. Similarly, majority of the farmers had a farming experience of more than fifteen years. Farming for many years increases the probability of adopting best agricultural practices that enhance productivity per acre (Sarker *et al*., 2021). The results further indicated that most of the small holder farmers had obtained land through inheritance. The result relates to studies on technology adoption in Africa that illustrate a significant effect of land ownership on adoption decisions (Kassie *et al*., 2013; Teklewold *et al*., 2013; Adetomiwa *et al*., 2020). A more secure land tenure arrangement increases the chances of adopting technologies unlike those relying on rented land. In addition, majority of the smallholder farmers cultivated drought tolerant crops. Growing short-season crops is an effective way of dealing with food insecurity since farmers obtain food all year round (Komba & Muchapondwa, 2018).

Multivariate probit results showed that market distance had a negative relationship with all the technologies except mixed farming and water harvesting. This could mean that market accessibility promoted access to adequate and reliable information on climate smart practices. Conversely, the positive relationship could signify less opportunity cost in adapting labor-intensive practices among rural households. In favor of the finding, argument by Amare & Simane (2017) revealed high willingness of rural households taking up adaptation in order to reduce climate related risks due to availability of less income-earning opportunities. On the other hand, access to credit facilities increased adoption of conservation agriculture and crop diversification. The credit facilities might encourage farmer participation in cooperative action or additional investments related to agricultural production. The result relates with Mustapha *et al.* (2017) who noticed that, farmers' purchasing power enables use of improved seeds hence positively impacting degree of market participation. The finding is also in line with by Ojo *et al*. (2019) and Wongnaa *et al*. (2018) who illustrated that inadequate access to farm credit impedes the adoption of improved technologies by farmers.

Agricultural extension contacts positively correlated with crop rotation, conservation agriculture and water harvesting. It is expected that farmers access to extension agents increases technical flow of agricultural information. Contrary to the expectation, a negative correlation with mixed farming was identified, contradicting the findings of Amikuzuno (2019), and Chandio and Jiang (2020). Maybe, extension agents in these Counties do not provide well packaged information on the selected improved technologies to smallholder farmers. In addition, ownership of title deeds positively increased adoption of crop rotation and crop diversification. This implies that farmers owning land had the right to use and are likely to use productivity enhancing practices and at the same time reducing climate risks. This finding relates to a study by Brüssow *et al*. (2017) that revealed a significant correlation between plot tenure security and drought-resistant crop variety adoption in Tanzania.

5.2.3 Effects of Climate Smart Technologies Adoption on Food Security

The mean food security scores of CSA users and non-users in the three Counties ranged from 22 to 24. This implies that food consumption across the three Counties is poor. The finding relates to a study by Bukania *et al*. (2014), who reported that households in eastern Kenya have persistent food insecurity characterized by land degradation, cycles of drought and famine, and reliance on food aid. Further, CSA users in Machakos and Kitui Counties were more food secure as compared to those in Makueni County. This could be attributed to County dynamics like cooperative membership, weather, population, land tenure, and extension services. The result relates to Mojo *et al*. (2017), who noticed that households with coffee farming membership and had access to extension services were more food secure as compared to those without.

More households in Kitui County had a poor FCS followed by households in Machakos and Makueni Counties. This can be attributed to the expansive area and high population of Kitui County as compared to Makueni and Machakos Counties. On the other hand, households in Makueni and Machakos had a higher borderline FCS than those in Kitui but the latter had a slightly higher acceptable FCS as compared to households in Machakos and Makueni. The results concur to Sirajuddin *et al*. (2017) who noted that weather, population, infrastructure, leadership and political influence were major contributors to food security in Barru Regency.

5.3 Conclusions

1. Most of the farmers in lower Eastern region of Kenya are conscious of climate change and sources for communicating climate information. However, frequent occurrence of droughts and early rains have devastating effects on household food security. Communication channels such as television, extension agents and local administrators increased uptake of conservation agriculture, agroforestry and intercropping. On the contrary, radio, mobile phone and neighbors/friends reduced adoption of crop diversification and agroforestry. This implies that improvement of these variables will facilitate dissemination of more appropriate information to smallholder farmers in lower Eastern Kenya.

2. Household age and size had a positive influence on uptake of agroforestry, crop diversification and water harvesting. Additionally, adequate access to agricultural extension officers and local administrators increased the likelihood of adopting conservation agriculture and water harvesting. Distance to the nearest market negatively influenced adoption of intercropping, crop rotation, conservation agriculture, agroforestry and crop diversification. It was evident that variables

affecting decisions to adopt a technology differ among technologies. In most cases, the probability of adopting a specific adaptation strategy significantly reduced with adoption of another adaptation strategy, suggesting substitutability effects. In some cases, probability of adopting a specific technology increased significantly with adoption of another adaptation strategy, indicating complementarity.

3. The study further revealed that the daily and weekly FCS were 63.5 and 36.5%, respectively. The rate of CSA technology that contributed to food Security were 24.2% (Machakos), 15.4% (Kitui) and 7.8% (Makueni). In addition, key CSA technologies influencing food security per County were; farm size (Machakos), distance to market (Makueni) and gender of household head (Kitui).

5.4 Recommendations

Based on findings the study made the following recommendations;

1. Agricultural stakeholders in Lower Eastern Kenya should prioritize promoting the availability of CSA adaptation information on agroforestry, crop rotation, and crop diversification through the local administrators as well as farmers' neighbors and friends.
2. To enhance adoption of CSA technologies among small scale famers in Lower Eastern Kenya, policy makers should consider both socio-economic factors (age, household size, farm size, gender of household head) and institutional factors (distance to markets, land ownership and extension service).
3. The agricultural stakeholders should develop strategies that can improve daily and weekly food consumption scores that are specific to the County food security determinants, for instance, strategies on family size (Machakos), distance to nearest market (Makueni), and gender of the household (Kitui) should be developed so as to achieve household food security.

REFERENCES

Abid, M., Scheffran, J., Schneider, U. A., & Ashfaq, M. (2015). Farmers' Perceptions of and adaptation strategies to climate change and their determinants: The case of Punjab province, Pakistan. *Journal of Earth System Dynamics*, *6*(1), 225–243.

Adebiyi, S., & Okunlola, J. O. (2013). Factors affecting adoption of cocoa farm rehabilitation techniques in Oyo State of Nigeria. *Journal of Agricultural Sciences*,. *9*(3), 258–265.

Adetomiwa, K., Iseoluwa, A. E., & Babatunde, O. S. (2020). Land tenure, land property rights and adoption of bio-fortified cassava in Nigeria: Implication for policy recommendations. *Journal of Agriculture and Sustainability*, *13*.

Akudugu, M., Guo, E., Dadzie, S. (2012). Adoption of modern agricultural production technologies by farm households in Ghana: What factors influence their decisions? *Journal of Biology, Agriculture and Healthcare 2*(3).

Amare, A., & Simane, B. (2017). Determinants of smallholder farmers' decision to adopt adaptation options to climate change and variability in the Muger Sub-basin of the Upper Blue Nile basin of Ethiopia. *Agriculture & food security*, *6*(1), 1-20.

Amikuzuno, J., Kuwornu, J. K., & Osman, D. T. (2019). Gender-based climate change impacts and adaptation strategies among smallholder farmers in Northern Ghana—What lessons for nationally-appropriate mitigation actions exist. *Climate change and Sub-Saharan Africa: The vulnerability and adaptation of food supply chain actors*, 241-269.

Amwata, D. A., Nyariki, D. M., & Musimba, N. R. (2016). Factors influencing pastoral and agropastoral household vulnerability to food insecurity in the drylands of Kenya: A case study of Kajiado and Makueni Counties. *Journal of International Development*, *28*(5), 771-787.

Arbuckle, J. G., Morton, L. W., & Hobbs, J. (2015). Understanding farmer perspectives on climate change adaptation and mitigation. *Environment and Behavior*, *47*(2), 205–234.

Aryal, J. P., Sapkota, T. B., Rahut, D. B., & Jat, M. L. (2020). Agricultural sustainability under emerging climatic variability: The role of climate-smart agriculture and relevant policies in India. *International Journal of Innovation and Sustainable Development*, *14*(2), 219-245.

Asayehegn, K., Temple, L., Sanchez, B., & Iglesias, A. (2017). Perception of climate change and farm level adaptation choices in Central Kenya. *Cahiers Agricultures*, *26*(2), 1–10.

Asfaw, S., Shiferaw, B., Simtowe, F., & Lipper, L. (2012). Impact of modern agricultural technologies on smallholder welfare : Evidence from Tanzania and Ethiopia. *Food Policy*, *37*(3), 283–295.

Ayuya, O. I., Kenneth, W. S., & Eric, G. O. (2012). Multinomial logit analysis of small-scale farmers' choice of organic soil management practices in Bungoma county, Kenya. *Current Research Journal of Social Sciences*, *4*(4), 314-322.

Baumgart-getz, A., Stalker, L., & Floress, K. (2012). Why farmers adopt best management practice in the United States : A meta-analysis of the adoption literature. *Journal of Environmental Management*, *96*(1), 17–25.

Beddington, J., Neufeldt, H., Campbell, B., Lezaks, D., Meinke, H., Jahn, M., Hellin, J., Wollenberg, E., Gulledge, J., Vermeulen, S., Rosenstock, T., Jarvis, A., Herrero, M., Declerck, F., Zougmoré, R., Scholes, M., Scholes, R., & De Pinto, A. (2016). Beyond climate-smart agriculture: Toward safe operating spaces for global food systems. *Sustainable Agriculture and Food Supply*, 337–346.

Bedeke, S., Vanhove, W., Gezahegn, M., Natarajan, K., & Van Damme, P. (2019). Adoption of climate change adaptation strategies by maize-dependent smallholders in Ethiopia. *NJAS-Wageningen Journal of Life Sciences*, *88*, 96-104.

Belay, A., Recha, J. W., Woldeamanuel, T., & Morton, J. F. (2017). Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. *Agriculture and Food Security*, *6*(1), 1–13.

Boruru, E. O., Ontita, E., Ogara, W. O., & Oguge, N. O. (2011). Climate change and the emergence of helter-skelter livelihoods among the pastoralists of Samburu East District, Kenya. In *Experiences of climate change adaptation in Africa* (pp. 97-110). Springer, Berlin, Heidelberg.

Bravo-Monroy, L., Potts, S. G., & Tzanopoulos, J. (2016). Drivers influencing farmer decisions for adopting organic or conventional coffee management practices. *Food Policy*, *58*, 49–61.

Brüssow, K., Faße, A., & Grote, U. (2017). Implications of climate-smart strategy adoption by farm households for food security in Tanzania. *Food security*, *9*(6), 1203-1218.

Bryan, E., Deressa, T. T., Gbetibouo, G. A., & Ringler, C. (2009). Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Journal of Environmental Science and Policy*, *12*(4), 413–426.

Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S., & Herrero, M. (2013). Adapting agriculture to climate change in Kenya: Household strategies and determinants. *Journal of Environmental Management*, *114*, 26–35.

Bukania, Z. N., Mwangi, M., Karanja, R. M., Mutisya, R., Kombe, Y., Kaduka, L. U., & Johns, T. (2014). Food insecurity and not dietary diversity is a predictor of nutrition status in children within semiarid agro-ecological zones in eastern Kenya. *Journal of nutrition and metabolism*, *20*(14), 1-9.

Bustos, P., Caprettini, B., & Ponticelli, J. (2016). Agricultural productivity and structural transformation: Evidence from Brazil. *American Economic Review*, *106*(6), 1320-65.

Chandio, A. A., & Jiang, Y. (2018). Determinants of Credit Constraints: Evidence from Sindh, Pakistan. *Emerging Markets Finance and Trade*, *54*(15), 3401-3410.

Cherotich, V. K., Saidu, O. S. E. N. I., & Bebe, B. O. (2012). Access to climate change information and support services by the vulnerable groups in semi-arid Kenya for adaptive capacity development. *African Crop Science Journal*, *20*, 169-180.

Chhetri, N., Chaudhary, P., Tiwari, P. R., & Yadaw, R. B. (2012). Institutional and technological innovation: Understanding agricultural adaptation to climate change in Nepal. *Applied Geography*, *33*(1), 142–150.

Clark, M. A., Domingo, N. G., Colgan, K., Thakrar, S. K., Tilman, D., Lynch, J., & Hill, J. D. (2020). Global food system emissions could preclude achieving the 1.5 and 2 C climate change targets. *Science*, *370*(6517), 705-708.

Cochran, William. G. (2007). *Sampling techniques*. John Wiley & Sons Incorporation.

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change*, *19*(2), 248–255.

Dulal, H. B., Brodnig, G., Thakur, H. K., & Green-Onoriose, C. (2010). Do the poor have what they need to adapt to climate change? A case study of Nepal. *Local Environment*, *15*(7), 621-635.

Dzanku, F., & Sarpong, D. (2010). Agricultural diversification, food self-sufficiency and food security in Ghana–the role of infrastructure and institutions. *African Smallholders: Food Crops, Markets and Policy. CAB International, Wallingford, UK*, 189-213.

Efole Ewoukem, T., Mikolasek, O., Aubin, J., Tomedi Eyango, M., Pouomogne, V., & Ombredane, D. (2017). Sustainability of fish pond culture in rural farming systems of Central and Western Cameroon. *International Journal of Agricultural Sustainability*, *15*(2), 208–222.

Emmanuel, D., Owusu-Sekyere, E., Owusu, V., & Jordaan, H. (2016). Impact of agricultural extension service on adoption of chemical fertilizer: Implications for rice productivity and development in Ghana. *NJAS - Wageningen Journal of Life Sciences*, *79*(2016), 41–49.

Ernah, Parvathi, P., & Waibel, H. (2016). Adoption of sustainable palm oil practices by Indonesian smallholder farmers. *Journal of Southeast Asian Economies*, *33*(3), 291–316.

Etwire, P. M., Al-Hassan, R. M., Kuwornu, J. K. M., & Osei-Owusu, Y. (2013). Smallholder farmers' adoption of technologies for adaptation to climate change in Northern Ghana. *Journal of Agricultural Extension and Rural Development*. *5*(6), 121–129.

FAO (Food and Agriculture Organization). (2008). Climate change and food security: A Framework Document. Rome, Italy.

FAO (Food and Agriculture Organization). (2010). Climate smart agriculture: Policies, practices and financing for food security, Adaptation and Mitigation. Rome, Italy.

FAO (Food and Agriculture Organization). (2011). The state of food insecurity in the world: How does international price volatility affect domestic economies and food security? FAO Publications, Rome, Italy.

FAO (Food and Agriculture Organization). (2013). Multiple dimensions of food security. The state of food insecurity in the world. Rome, Italy.

FAO (Food and Agriculture Organization). (2015). Report of the food and agriculture organization concerning United Nations. Nairobi, Government publisher.

FAO (Food and Agriculture Organization). (2018). Climate change and food security: A Framework Document. Rome, Italy.

Fasina, O.O., 2015. Determents of radio agricultural programs listenership: A case study of FUTA FM 93.1 radio station in Ondo state, Nigeria. Agricultural Communications.

Fisher, M., & Carr, E. R. (2015). The influence of gendered roles and responsibilities on the adoption of technologies that mitigate drought risk : The case of drought-tolerant maize seed in eastern Uganda. *Global Environmental Change, 35*, 82–92.

Folitse, B. Y., Manteaw, S. A., Dzandu, L. P., Obeng-Koranteng, G., & Bekoe, S. (2019). The determinants of mobile-phone usage among small-scale poultry farmers in Ghana. *Information Development*, *35*(4), 564-574.

Ford, J. D., Berrang-Ford, L., Bunce, A., McKay, C., Irwin, M., & Pearce, T. (2015). The status of climate change adaptation in Africa and Asia. *Regional Environmental Change*, *15*(5), 801-814.

Gebrehiwot, T., & Van Der Veen, A. (2013). Farm level adaptation to climate change: The case of farmer's in the ethiopian highlands. *Environmental Management*, *52*(1), 29–44.

Gebremariam, G., & Tesfaye, W. (2018). The heterogeneous effect of shocks on agricultural innovations adoption: Micro econometric evidence from rural Ethiopia. *Food Policy*, *74*, 154-161.

Girvetz, E. H., Rosenstock, T. S., Corner-Dolloff, C., & Lamanna, C. (2015). 25 million African Farming Families by 2025: *Science-Development Partnerships for Scaling Climate-Smart Agriculture*.

Gladys, K. V. (2017). Rainfall and temperature variability and its effect on food security in Kitui county, Kenya. *International Journal of Development and Sustainability*, *6*(8), 924-939.

Golub, A. A., Henderson, B. B., Hertel, T. W., Gerber, P. J., Rose, S. K., & Sohngen, B. (2013). Global climate policy impacts on livestock, land use, livelihoods, and food security. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(52), 20894–20899.

Gupta, D., Fischer, H., Shrestha, S., Ali, S. S., Chhatre, A., Devkota, K., ... & Rana, P. (2021). Dark and bright spots in the shadow of the pandemic: Rural livelihoods, social vulnerability, and local governance in India and Nepal. *World Development*, *141*, 105370.

Habiba, U., Shaw, R., & Takeuchi, Y. (2012). Farmer's perception and adaptation practices to cope with drought: Perspectives from Northwestern Bangladesh. *International Journal of Disaster Risk Reduction*, *1*(1), 72–84.

Hadush, M. (2018). Welfare and food security response of animal feed and water resource scarcity in Northern Ethiopia. *Agricultural and Food Economics*, *6*(1), 1-24.

Harvey, C. A., Chacón, M., Donatti, C. I., Garen, E., Hannah, L., Andrade, A., … Wollenberg, E. (2014). Climate-smart landscapes: Opportunities and challenges for integrating adaptation and mitigation in tropical agriculture. *Conservation Letters*, *7*(2), 77–90.

Hausman, J., and Mc-Fadden, D. (1984). Specification tests for Multinomial Logit Model. *Econometrica*, *52*, 1219-1240.

Hellin, J., Bellon, M. R., & Hearne, S. J. (2014). Maize landraces and adaptation to climate change in Mexico. *Journal of Crop Improvement*, *28*(4), 484–501.

Howley, P., Donoghue, C. O., & Heanue, K. (2012). Factors affecting farmers' adoption of agricultural innovations: A panel data analysis of the use of artificial insemination among dairy farmers in Ireland. *Journal of Agricultural Science*, *4*(6), 171.

Imran, M. A., Ali, A., Ashfaq, M., Hassan, S., Culas, R., & Ma, C. (2018). Impact of Climate Smart Agriculture (CSA) practices on cotton production and livelihood of farmers in Punjab, Pakistan. *Journal of Sustainability (Switzerland)*, *10*(6).

IPCC (Intergovernmental Panel on Climate Change). (1995). Climate Change and Cities, Contributions of Working Group I to the First Assessment Report of the Urban Climate Change Research Network for the Intergovernmental Panel on Climate Change, Cambridge University Press, New York.

IPCC (Intergovernmental Panel on Climate Change). (2001). Climate change 2001: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University press.

IPCC (Intergovernmental Panel on Climate Change). (2007). Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University press.

IPCC (Intergovernmental Panel on Climate Change) . (2007). The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University press.

IPCC (Intergovernmental Panel on Climate Change). (2012). Managing the risks of extreme events and disasters to advance climate change adaptation. A special Report of Working Groups I and II of the 155 Intergovernmental Panel on Climate Change. In C. Field, T. Barros, D. Stocker, D. Qin, K. Dokken, M. Ebi, et al. (Ed.). Cambridge, UK and New York, NY, U.S.A: Cambridge University Press.

IPCC (Intergovernmental Panel on Climate Change). (2014). Climate change 2014: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University press.

Jarvis, D. I., Hodgkin, T., Sthapit, B. R., Fadda, C., & Lopez-Noriega, I. (2011). An Heuristic framework for identifying multiple ways of supporting the conservation and use of traditional crop varieties within the agricultural production system. *Critical Reviews in Plant Sciences*, *30*(1–2), 125–176.

Kalungu, J. W., & Leal Filho, W. (2018). Adoption of appropriate technologies among smallholder farmers in Kenya. *Climate and Development*, *10*(1), 84-96.

Kassie, M., Jaleta, M., Shiferaw, B., Mmbando, F., & Mekuria, M. (2013). Adoption of interrelated sustainable agricultural practices in smallholder systems: Evidence from rural Tanzania. *Technological forecasting and social change*, *80*(3), 525-540.

Ketema, M., & Kebede, D. (2017). Adoption intensity of inorganic fertilizers in maize production: empirical evidence from smallholder farmers in eastern Ethiopia. *Journal of Agricultural Science*, *9*(5),124-132.

Khatri-chhetri, A., Aggarwal, P. K., Joshi, P. K., & Vyas, S. (2016). Farmers ' prioritization of climate-smart agriculture (CSA) technologies. *Journal of Agricultural Systems.151*, 184-191.

Khisa, G., Oteng, S., M. S. (2014). Effect of Climate change on small scale agricultural production and food security in Kitui District , Kenya. *The Journal of Agriculture and Natural Resources Sciences*, *1*(1), 34–44.

Kide, G.T., 2014. Smallholder farmers' adaptation strategies to climate change in Ethiopia: Evidence from Adwa Woreda of Tigray Region. Mekelle University.

Kichamu, E. A., Ziro, J. S., Palaniappan, G., & Ross, H. (2018). Climate change perceptions and adaptations of smallholder farmers in Eastern Kenya. *Environment, development and sustainability*, *20*(6), 2663-2680.

KNBS (Kenya National Bureau of Statistics). (2019). Population by County and Sub-County.Volume 1. KNBS, Nairobi.

Kogo, B. K., Kumar, L., & Koech, R. (2021). Climate change and variability in Kenya: a review of impacts on agriculture and food security. *Environment, Development and Sustainability*, *23*(1), 23-43.

Komba, C., & Muchapondwa, E. (2018). Adaptation to climate change by smallholder farmers in Tanzania. In *Agricultural adaptation to climate change in Africa* (pp. 129-168). Routledge.

Kothari, C. R. (2004). Research methodology: Methods and techniques. New Age International.

Kotir, J. H. (2011). Climate change and variability in Sub-Saharan Africa: A review of current and future trends and impacts on agriculture and food security. *Environment, Development and Sustainability*, *13*(3), 587–605.

Kuntashula, E., Chibwe, T., & Chabala, L. M. (2017). Enabling agricultural transformation through climate change policy engagement. *Smart Technologies for Sustainable Smallholder Agriculture* (233–256).

Lalani, B., Dorward, P., Holloway, G., & Wauters, E. (2016). Smallholder farmers' motivations for using Conservation Agriculture and the roles of yield, labour and soil fertility in decision making. *Agricultural Systems*, *146*, 80–90.

Lambrecht, I., & Vanlauwe, B. (2014). Understanding the Process of Agricultural technology adoption: Mineral fertilizer in Eastern Democratic Congo. *World Development*, *59*, 132–146.

Lipper, L., Thornton, P., Campbell, B. M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., Hottle, R., Jackson, L., Jarvis, A., Kossam, F., Mann, W., McCarthy, N., Meybeck, A., Neufeldt, H., Remington, T., … Torquebiau, E. F. (2014). Climate-smart agriculture for food security. *Nature Climate Change*, *4*(12), 1068–1072.

Lobell, D. B., Burke, M. B., Tebaldi, C., Mastrandrea, M. D., Falcon, W. P., & Naylor, R. L. (2008). Prioritizing climate change adaptation needs for food security in 2030. *Science*, *319*(5863).

Lobell, D. B., & Gourdji, S. M. (2012). The influence of climate change on global crop productivity. *Journal of Plant Physiology*, *160*(4), 1686–1697.

Makate, C. (2019). Effective scaling of climate smart agriculture innovations in African smallholder agriculture: A review of approaches, policy and institutional strategy needs. *Environmental Science and Policy*, *96*(August 2018), 37–51.

Makate, C., & Makate, M. (2019). Interceding role of institutional extension services on the livelihood impacts of drought tolerant maize technology adoption in Zimbabwe. *Technology in Society*, *56*(May), 126–133.

Makate, C., Makate, M., & Mango, N. (2018). Farm household typology and adoption of climate-smart agriculture practices in smallholder farming systems of southern Africa. *African Journal of Science, Technology, Innovation and Development*, *10*(4), 421–439.

Makate, C., Makate, M., Mango, N., & Siziba, S. (2019). Increasing resilience of smallholder farmers to climate change through multiple adoption of proven climate-smart agriculture innovations. Lessons from Southern Africa. *Journal of Environmental Management*, *231*(August 2018), 858–868.

Manda, J., Alene, A. D., Gardebroek, C., Kassie, M., & Tembo, G. (2016). Adoption and impacts of sustainable agricultural practices on maize yields and incomes: Evidence from Rural Zambia. *Journal of Agricultural Economics*, *67*(1), 130–153.

Mariano, M. J., Villano, R., & Fleming, E. (2012). Factors influencing farmers' adoption of modern rice technologies and good management practices in the Philippines. *Agricultural Systems*, *110*, 41–53.

Masesi, G. K. (2019). *Access and Utilization of Seasonal Climate Forecast Among Small Holder Farmers in Masinga Sub-County, Machakos County, Kenya* (Doctoral dissertation, Chuka University).

McCubbin, S. G., Pearce, T., Ford, J. D., & Smit, B. (2017). Social–ecological change and implications for food security in funafuti, tuvalu. *Ecology and Society*, *22*(1).

Meijer, S. S., Catacutan, D., Ajayi, O. C., Sileshi, G. W., & Nieuwenhuis, M. (2015). The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. *International Journal of Agricultural Sustainability*, *13*(1), 40–54.

Mekonnen, D. A., Gerber, N., & Matz, J. A. (2018). Gendered social networks, agricultural innovations, and farm productivity in Ethiopia. *World Development*, *105*, pp321-3355.

Mignouna, B., Manyong, M., Rusike, J., Mutabazi, S., & Senkondo, M. (2011). Determinants of Adopting imazapyr-resistant maize technology and its impact on household income in Western Kenya: AgBioforum, 14(3), 158-163. Hall, B. and Khan, B. (2002) Adoption of new technology. New Economy Handbook.

Misra, A. K. (2014). Climate change and challenges of water and food security. *International Journal of Sustainable Built Environment*, *3*(1), 153–165.

Mittal, S., & Mehar, M. (2016). Socio-economic Factors affecting adoption of modern information and communication technology by farmers in India: Analysis Using Multivariate Probit Model. *Journal of Agricultural Education and Extension*, *22*(2), 199–212.

Mottaleb, K. A., Krupnik, T. J., & Erenstein, O. (2016). Factors associated with small-scale agricultural machinery adoption in Bangladesh: Census findings. *Journal of Rural Studies*, *46*, 155–168.

Mtega, W. P. (2018). The usage of radio and television as agricultural knowledge sources: The case of farmers in Norogoro region of Tanzania. *International Journal of Education and Development using Information and Communication Technology*, *14*(3), 252-266.

Muema, E., Mburu, J., Coulibaly, J., & Mutune, J. (2018). Determinants of access and utilisation of seasonal climate information services among smallholder farmers in Makueni County, Kenya. *Heliyon*, *4*(11), e00889.

Munang, R., Nkem, J. N., & Han, Z. (2013). Using data digitalization to inform climate change adaptation policy : Informing the future using the present. *Weather and Climate Extremes*, *1*(1210), 17–18.

Muita, R., Dougill, A., Mutemi, J., Aura, S., Graham, R., Awolala, D., & Opijah, F. (2021). Understanding the role of user needs and perceptions related to sub-seasonal and seasonal forecasts on farmers' decisions in Kenya: a systematic review. *Frontiers in Climate*, *3*.

Murage, A. W., Midega, C. A. O., Pittchar, J. O., Pickett, J. A., & Khan, Z. R. (2015). Determinants of adoption of climate-smart push-pull technology for enhanced food security through integrated pest management in eastern Africa. *Food Security*, *7*(3), 709-724.

Murgor, D. K., Cheserek, G., & Nduru, G. M. (2018). Climate and weather informational services and products for maize and wheat farmers in Uasin Gishu County, Kenya. *Africa Environmental Review Journal*, *3*(1), 30-42.

Mustapha, S., Mohammed, T., & Abukari, I. (2017). Application of multinomial logistic to smallholder farmers' market participation in Northern Ghana. *International Journal of Agricultural Economics*, *2*(3), 55-62.

Mutenje, M. J., Farnworth, C. R., Stirling, C., Thierfelder, C., Mupangwa, W., & Nyagumbo, I. (2019). A cost-benefit analysis of climate-smart agriculture options in Southern Africa: Balancing gender and technology. *Ecological Economics, 163*, 126-137.

Mwadalu, R., & Mwangi, M. (2013). The potential role of sorghum in enhancing food security in semi-arid eastern Kenya: A review. *Journal of Applied Biosciences, 71(1),* 5786.

Narine, L. K., Harder, A., & Roberts, T. G. (2019). Farmers' intention to use text messaging for extension services in Trinidad. *The Journal of Agricultural Education and Extension*, *25*(4), 293-306.

Namara, R. E., Gebregziabher, G., Giordano, M., & De Fraiture, C. (2013). Small pumps and poor farmers in Sub-Saharan Africa: An assessment of current extent of use and poverty outreach. *Water International*, *38*(6), 827–839.

Nambiro, E., & Okoth, P. (2013). What factors influence the adoption of inorganic fertilizer by maize farmers? A case of Kakamega District, Western Kenya. *Scientific Research and Essays*, *8*(5), 205–210.

Ndung'u, C. K., & Muriu-Ng'ang'a, F. W. (2021). Assessment of farmers' vulnerability to climate variability and extreme events: Evidence from dry Kitui, Kenya. *International Journal of Environment, Agriculture and Biotechnology*, *6*(1).

Ndiritu, S. W., Kassie, M., & Shiferaw, B. (2014). Are there systematic gender differences in the adoption of sustainable agricultural intensification practices? Evidence from Kenya. *Food Policy*, *49*, 117-127.

Ngigi, M. W., Mueller, U., & Birner, R. (2017). Gender differences in climate change adaptation strategies and participation in group-based approaches: An Intra-household Analysis From Rural Kenya. *Ecological Economics*, *138*, 99–108.

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

Nunes, B., Bennett, D., & Marques, S. (2014). Sustainable agricultural production: An investigation in Brazilian semi-arid livestock farms. *Journal of Cleaner Production*, *64*, 414–425.

Nxumalo, K. K. S., & Oladele, O. I. (2013). Factors affecting farmers' participation in agricultural programme in Zululand district, Kwazulu Natal Province, South Africa. *Journal of Social Sciences*, *34*(1), 83-88.

Nyasimi, M., Kimeli, P., Sayula, G., Radeny, M., Kinyangi, J., & Mungai, C. (2017). Adoption and dissemination pathways for climate-smart agriculture technologies and practices for climate-resilient livelihoods in Lushoto, Northeast Tanzania. *Climate*, *5*(3), 63.

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.

Okuthe, K. I., Ngesa, U. F. and Ochola, W. W., (2013). Influence of institutional factors on adoption of improved sorghum varieties and technologies by small-scale farmers in Western Kenya. *International Journal of Humanities and Social Science, 3*(16),196-207.

Ojo, M. A., Saleh, D. B., Coker, A. A. A., & Ojo, A. O. (2019). Effect of improved seed technology adoption on small-scale sorghum farmers' productivity in Kebbi State, Nigeria. *Agricultural Science & Technology (1313-8820)*, *11*(1).

Partey, S. T., Zougmoré, R. B., Ouédraogo, M., & Campbell, B. M. (2018). Developing climate-smart agriculture to face climate variability in West Africa: challenges and lessons learnt. *Journal of cleaner Production*, *187*, 285-295.

Ramirez, A. (2013). The influence of social networks on agricultural technology adoption. *Journal of Social and Behavioral Sciences*, *79*, 101–116.

Reidsma, P., Ewert, F., Lansink, A. O., & Leemans, R. (2010). Adaptation to climate change and climate variability in European agriculture: The importance of farm level responses. *European Journal of Agronomy, 32(1), 91–102.*

Rigolot, C., de Voil, P., Douxchamps, S., Prestwidge, D., Van Wijk, M., Thornton, P. K., Rodriguez, D., Henderson, B., Medina, D., & Herrero, M. (2017). Interactions between intervention packages, climatic risk, climate change and food security in mixed crop–livestock systems in Burkina Faso. *Agricultural Systems*, *151*, 217–224.

Roco, L., Engler, A., Bravo-Ureta, B., & Jara-Rojas, R. (2014). Farm level adaptation decisions to face climatic change and variability: Evidence from Central Chile. *Environmental Science and Policy, 44*, 86–96.

Saguye, T. S. (2017). Determinants of adoption of sustainable land management (SLM) practices among smallholder farmers' in Jeldu District, West Shewa Zone, Oromia Region, Ethiopia. *Global Journal of Science Frontier Research, 7*, 60-76.

Sarker, M. R., Galdos, M. V., Challinor, A. J., & Hossain, A. (2021). A farming system typology for the adoption of new technology in Bangladesh. *Food and Energy Security*, e287.

Saylor, A., Gramig, B. M., & Stalker, L. (2016). Climate change beliefs, risk perceptions, and adaptation behavior among Midwestern United States crop farmers. *Journal of Climate Risk Management*, 15, 8-17.

Serdeczny, O., Adams, S., Baarsch, F., Coumou, D., Robinson, A., Hare, W., ... & Reinhardt, J. (2017). Climate change impacts in Sub-Saharan Africa: from physical changes to their social repercussions. *Regional Environmental Change*, *17*(6), 1585-1600.

Shadreck Zhou, I. J. M., & and Bruce Mtigwe. (2013). Smallholder agricultural commercialization for income growth and poverty alleviation in southern Africa: A review. *African Journal of Agricultural Research*, *8*(22), 2599–2608.

Shankar, S., & Shikha. (2017). Impacts of climate change on agriculture and food security. In *Biotechnology for Sustainable Agriculture: Emerging Approaches and Strategies*. Elsevier Inc.

Shiferaw, B., Tesfaye, K., Kassie, M., Abate, T., Prasanna, B. M., & Menkir, A. (2014). Managing vulnerability to drought and enhancing livelihood resilience in sub-Saharan Africa: Technological, institutional and policy options. *Weather and Climate Extremes*, *3*, 67–79.

Shikuku, K. M. (2019). Information exchange links, knowledge exposure, and adoption of agricultural technologies in northern Uganda. *World Development*, *115*, 94-106.

Simotwo, H. K., Mikalitsa, S. M., & Wambua, B. N. (2018). Climate change adaptive capacity and smallholder farming in Trans-Mara East sub-County, Kenya. *Geoenvironmental Disasters*, *5*(1), 1-14.

Sirajuddin, S. N., Siregar, A. R., & Mappigau, P. (2017). Adoption Rate of beef breeders technology following partnership system in Barru Regency. *American-Eurasian Journal of Sustainable Agriculture*, *11*(6), 31-34.

Ssentamu, N., Dubois, T., & Qaim, M. (2012). Heterogeneous information exposure and technology adoption *: The case of tissue culture bananas in Kenya*. *43*, 1–13.

Teklewold, H., Kassie, M., & Shiferaw, B. (2013). Adoption of multiple sustainable agricultural practices in rural Ethiopia. *Journal of Agricultural Economics*, *64*(3), 597-623.

Teshome, M., & Baye, A. (2018). Climate variability, communities' perceptions and land management strategies in Lay Gayint Woreda, Northwest Ethiopia. *Journal of Degraded and Mining Lands Management*, *5*(3),1217.

Tiamiyu, M., Bankole, A. & Agbonlahor, R., 2011. The Impact of ict investment, ownership and use in the cassava value chain in south Western Nigeria. *African Journal of Science, Technology, Innovation and Development, 3*(3), pp.179–201.

Tokede, A. M., Banjo, A. A., Ahmad, A. O., Fatoki, O. A., & Akanni, O. F. (2020). Farmers' knowledge and attitude towards the adoption of agroforestry practices in Akinyele Local Government Area, Ibadan, Nigeria. *Journal of Applied Sciences and Environmental Management*, *24*(10), pp1775-1780.

Totin, E., Segnon, A. C., Schut, M., & Affognon, H. (2018). Institutional perspectives of climate-smart agriculture : *A Systematic Literature Review*. 1–20.

Uddin, M., Bokelmann, W., & Entsminger, J. (2014). Factors affecting farmers' adaptation strategies to environmental degradation and climate change effects: A Farm Level Study in Bangladesh. *Climate*, *2*(4), 223–241.

UNDP (United Nations Development Programme). (2011). Human development report: sustainability and equity: A better future for all. New York, (NY): United Nations Publications. Washington, D.C.USA.

UN (United Nations). (2019). *The Sustainable Development Goals Report 2019*. New York: United Nations.

Urassa, N. S., & Mvena, Z. S. K. (2016). Determinants of the use of cell phones in access to beef cattle market information for smallholders in Mpwapwa District, Tanzania. *Huria: Journal of the Open University of Tanzania*, *22*(1), 116-131.

Vermeulen, S. J., Aggarwal, P. K., Ainslie, A., Angelone, C., Campbell, B. M., Challinor, A. J., Hansen, J. W., Ingram, J. S. I., Jarvis, A., Kristjanson, P., Lau, C., Nelson, G. C., Thornton, P. K., & Wollenberg, E. (2012). Options for support to agriculture and food security under climate change. *Environmental Science and Policy*, *15*(1), 136–144.

Wainaina, P., Tongruksawattana, S., & Qaim, M. (2016). Tradeoffs and complementarities in the adoption of improved seeds, fertilizer, and natural resource management technologies in Kenya. *Journal of Agricultural Economics 47(3)*, 351–362.

Wassmann, R., Villanueva, J., Khounthavong, M., Okumu, B. O., Vo, T. B. T., & Sander, B. O. (2019). Adaptation, mitigation and food security: Multi-criteria ranking system for climate-smart agriculture technologies illustrated for rainfed rice in Laos. *Global Food Security*, *23*, 33-40.

WHO (World Health Organization). (2019). The state of food security and nutrition in the world 2019: safeguarding against economic slowdowns and downturns (Vol. 2019). Food & Agriculture Organization. Rome, Italy.

WMO (World Meteorological Organization). 2018: The State of the Global Climate in 2018. World Meteorological Organization.Geneva, Switzerland.

Wongnaa, C. A., Awunyo-Vitor, D., & Bakang, J. E. A. (2018). Factors affecting adoption of Maize production technologies: A study in Ghana. *Journal of Agricultural Sciences*, *13*(1), 81-99.

World Bank. (2013). Turn down the heat: Climate extremes, regional impacts, and the case for resilience.The World Bank. Washington, D.C.

World Bank. (2011). Climate-smart agriculture: increased productivity and food security, enhancing resilience and reduced carbon emissions for sustainable development, opportunities and challenges for a converging agenda: country examples. The World Bank. Washington, D.C.

WFP (World Food Summit). (1996). World summit on food security bulletin, World Food Summit, 13-17 November 1996, FAO Headquarters, Rome, Italy.

WFP (World Food Program). (2009). Food consumption analysis: Calculation and use of the food consumption score in food security analysis. Rome, Italy.

Yekinni, O. T., & Afolabi, C. O. (2019). Farmers' assessment of the effectiveness of extension communication methods used in Ogbomoso Agricultural Zone of Oyo-State, Nigeria. *Journal of Agricultural Extension*, *23*(3), 126-134.

APPENDICES

APPENDIX I: Correlation Matrix

	gender	age	education level	household size	farm size	television	radio	mobile phone	extension agents	local admin.	Neighbors and friends
gender	1.00										
age	-0.24	1.00									
education level	-0.17	-0.18	1.00								
household size	-0.04	0.078	-0.08	1.00							
farm size	-0.15	0.19	0.01	0.00	1.00						
television	-0.11	0.01	0.08	-0.06	-0.03	1.00					
radio	0.01	0.03	0.06	-0.05	-0.04	0.06	1.00				
mobile phone	0.01	-0.09	0.03	-0.05	0.01	0.02	0.07	1.00			
extension agents	-0.05	-0.01	-0.03	0.01	0.09	-0.13	-0.03	0.23	1.00		
local administrators	-0.01	-0.02	-0.03	0.07	0.06	-0.09	0.01	0.20	0.22	1.00	
neighbors and friends	-0.01	0.04	-0.06	-0.04	0.02	-0.14	-0.05	0.13	0.14	0.16	1.00

APPENDIX II: Study Questionnaire

Welcome to the survey. You are among several farmers in this area who have been selected for this study. The study seeks to evaluate the selected factors influencing adoption of Climate Smart Agriculture (CSA) technologies and overall effect on household food security status. The information you give will be strictly confidential.

SECTION 1: GENERAL INFORMATION

Household Identification No	
Date of data collection	
County	
Ward	
Village	

SECTION 2: DEMOGRAPHIC INFORMATION

A1 Gender of the household head	1=male 0=female
A2 Age of the household head in years	
A3 Marital status of the household head	1=single 2=married 3=divorced 4=separated
A4 Highest education level of the household head	1=no formal education 2=primary 3=secondary 4=college 5= university
A5 Main occupation of the household head	1= farming 2= business/self-employed 3=government employed 4=daily wager
A6 Number of household members (only those who take meals in the household)	

SECTION 3: CLIMATE CHANGE ADAPTATION INFORMATION

1. Do you perceive that climate change and variability is being experienced in this area? Yes [ ] No [ ]

2. If 'Yes' to No 1, which major weather patterns make you conclude that climate change and variability is occurring for the last 5 years?

Weather Pattern	**Yes**	**No**
Early rains		
Long rainfall		
Low temperatures		
High/extreme temperatures		
Excessive drought conditions		
Excessive cloudy periods		

If no, proceed to question 3.

3. Are you aware of climate smart agricultural practices?

   Yes [ ] No [ ]

4. If 'Yes' to No. 3, which major channels of communications do you use to receive this information from?

Channel	**Yes**	**No**
Radio		
Television		
Mobile phone		
Extension agents		
Neighbors and friends		
Local administrators		

If no, proceed to question 7.

5. If you have received information on climate smart agriculture, are you using the information?

Technology use	**Yes**	**No**
User		
Non-user		

If no, proceed to question 7.

6. If 'Yes' to No. 5, which climate smart practices are you practicing on your farm?

Climate smart practice	**Yes**	**No**
Mixed farming		
Crop diversification		
Conservation agriculture		
Planting of trees (Agroforestry)		
Intercropping		
Water harvesting		
Crop rotation		

SECTION 4: SOCIO-ECONOMIC AND INSTITUTIONAL ASPECTS

7. Which is the main farming system?

Crop production only [ ] Livestock rearing only [ ]

Mixed farming [ ]

8. For how long have you been involved in the above farming system(s)

Period of farming	**Yes**	**No**
Less than 5 years		
5-10 years		
11-15 years		
More than 15 years		

9. Which type of crops are grown on your farm?

Crop	**Yes**	**No**
Maize		
Beans		
Millet		
Cassava		
Green grams		
Pigeon pea		
Cow pea		

10. On average, how much income can you generate from your farming activities per year (in kes)?..

11. Which type of land do you practice agricultural activities on?

Type of land	**Yes**	**No**
Inherited		
Own land		
Rented land		
Communal land		
Own plus rent		
Own plus inherited		
Own plus communal		

12. Do you access credit and loan facilities?

Yes [ ]   No [ ]

13. If 'Yes' to No. 12 above, from which sources do you access credit?

Credit source	**Yes**	**No**
Banks		
Farmer cooperative organizations		
Microfinance organizations		

Table banking		
Remittances		
Own business		

14. Are there any issues constraining you from accessing loans and credits?

Yes [ ] No [ ]

15. If 'Yes' to No. 14 above, which issues constrain you from accessing loans and credit facilities?

Constrain	**Yes**	**No**
High interest rates		
Lack of security		
Inadequate banking services		
Inadequate access to information on credit facilities		
Inadequate time		

15. How far is your farm from the nearest main road or market (in km)?

…………………………………………………..

16. Do you have access to agricultural inputs?

Yes [ ] No [ ]

17. If 'No' to No. 16, which factors hinder you from accessing agricultural inputs?

Challenge	**Yes**	**No**
Long distance to the market		
Poor roads		
Limited funds		
High cost		
Inadequate information on availability and use		

18. Do you have access to agricultural extension services?

Yes [ ] No [ ]

19. If 'Yes' to No. 18, which extension training methods do you access?

Challenge	**Yes**	**No**
Farmers trainings and visits		
Agricultural traing centers (ATCs)		
Field demonstrations		
Farmer field schools (FFS)		
Internet delivery		
Telephone communications		

20. If 'No' to No. 18, which factors hinder you from accessing extension training methods?

Challenge	**Yes**	**No**
Low financial resources		
Inadequate information on extension services		
Fewer extension officers are available		
Payment for extension services is expensive		
Research centers are located too far		

SECTION 5: FOOD SECURITY

21. What is the frequency of consumption of local foods in your household?

Daily [ ] Weekly [ ] Monthly [ ]

22. Where do you obtain food and vegetables from?

Own production [ ] Own + Market purchase [ ]

Market purchase only [ ]

23. In the last month, did you or anyone in your household skip meals, reduce portions, or feel hungry because you did not have enough food?

Yes [ ]   No [ ]

24. In the last seven days, did your household eat any of the food categories listed below? (Tick type of food eaten per day) and leave a blank space on each day the food was not eaten.

		Days Ago						
S/N	**Food item**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
1.	Ugali (maize meal)							
2.	Porridge							
3.	Millet meal							
4.	Sorghum meal							
5.	Wheat meal							
6.	Rice							
7.	Green grams							
8.	Beans							
9.	Beef/pork/poultry/fish							
10.	Eggs							
11.	Vegetables							
12.	Tubers							
13.	Dolichos							
14.	Sugar							
15.	Cooking fat/oils							
16.	Tea with milk/fresh /sour							
17.	Fruits							

Thank you