EFFECT OF CLIMATE SMART AGRICULTURAL PRACTICES ON FOOD SECURITY OF SMALL SCALE FARMERS IN TESO NORTH SUB-COUNTY, KENYA

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A Thesis Submitted to the Graduate School in Partial Fulfillment for the Requirements of the Award of Master of Science Degree in Agricultural and Applied Economics of Egerton University

EGERTON UNIVERSITY

NOVEMBER, 2017

DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been presented for an award of a degree, diploma or certificate in Egerton University or any other University.

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RECOMMENDATION

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DEDICATION

I dedicate this work to my parents Isaac Wekesa and Mary Musimbi, who have always invested in me their time and resources to enable me pursue my education. To my siblings: Christine, Phanice, Branice, Marion and Claris for their undying love and moral support.

ACKNOWLEDGEMENT

May I take this opportunity to thank the Almighty God for the love, care and gift of good health which enabled through this work. I would also like to extend my profound gratitude to Egerton University for the chance awarded to me to pursue Collaborative Masters of science in Agricultural and Applied Economics (CMAAE), which is a rare chance. I also sincerely appreciate the African Economic Research Consortium (AERC) for funding this research and my entire Master of Science programme. Additionally, the opportunity presented by the Collaborative Masters of science in Agricultural and Applied Economics (CMAAE) secretariat to pursue specialized and electives training at the University of Pretoria, South Africa, which has been the hallmark of my studies is abundantly appreciated.

My special thanks go to my supervisors, Prof. J.K. Lagat, and Dr. O.I. Ayuya for their guidance and relentless support. Their persuasiveness, keen interest and challenges sharpened my thinking. I am equally indebted to the course lecturers for their invaluable insights, advice and constructive criticisms during the proposal, execution and write up of this thesis. Their tireless and invaluable contribution, and above all, their dedication and patience in guiding me from the infancy to the maturity of this thesis have been priceless.

My appreciation also goes to my fellow colleagues for sharing with me useful ideas during the entire period of my study and research. Many thanks also go to farmers in Teso North Sub-County for their enthusiasm and collaboration during the entire period of my field work. Finally, I thank all the enumerators who assisted me during data collection.

ABSTRACT

Climate change is a current threat to food production and food security. Temperature rise and variability in rainfall patterns has had serious consequences on crop and livestock production in Teso North Sub-County leading to a decline in food production. Climate Smart Agriculture (CSA) is the way to turn around the situation to more resilience and higher agricultural productivity leading to improved food security status. Although CSAs have been promoted in the region, not all farmers have adopted fully and their effects on food security are not clear. This study sought to evaluate the uptake of CSAs and their effects on food security among small scale farmers. Multistage sampling technique was employed in sampling 384 farmers in Teso North Sub-County. Primary data was collected through face-to-face interviews using pre tested interview schedules. Food security was measured by both Household Food Consumption Score (HFCS) and Household Dietary Diversity Score (HDDS). To group CSA practices, Principal component analysis (PCA) was applied and Poisson Regression analysis was used in analysing demand for CSA practices. Multinomial Endogenous Switching Regression was employed in analysing the effect of using the practices on household food security status. Results revealed that 14 individual CSA practices which were grouped into 4 were actively in use. The groups included: crop management, field management, farm risk reduction and specific soil management practices. The results also showed that demand for CSA practices was positively influenced by gender of the household head, household size, participation in off-farm employment, farm size, group membership, annual contacts with extension service agents, credit access and negatively influenced by age of the household head. The mean number of CSA strategies used by farmers was 2 applied by 44.8% of farmers. Most importantly, it was evident that CSA practices had a great potential to solve food security challenges. A complete package with crop management, field management, farm risk reduction and specific soil management practices had the highest implication to food security. To improve demand for CSAs, farmers need to be motivated to join and participate in farmer organizations through which they could gain access to extension information and credit. Additionally, farmers should be sensitized on the need to invest in farm productive assets in order to absorb the risks of climate change while also enabling them to benefit from use of CSAs which require these important assets. Finally, land fragmentation should be discouraged through civic education and provision of alternative income generating activities for farmers to benefit from CSAs when practiced on relatively bigger land.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACCCA	Association of California Community College Administrators
CC	Climate Change
COP	Conference of Parties
CSA	Climate Smart Agriculture
EMCA	Environment Management Coordination Act
FACE	Free Air Carbon Enrichment
FARA	Forum for Agricultural Research in Africa
FAO	Food and Agriculture Organization
FICCF	Finance Innovation for Climate Change Fund
GHG	Green House Gas
GOK	Government of Kenya
HDDS	Household Dietary Diversity Score
HFCS	Household Food Consumption Score
ICRAF	International Centre for Research in Agro-forestry
IPCC	Intergovernmental Panel on Climate Change
KMD	Kenya Metrological Department
KNBS	Kenya National Bureau of Statistics
LULUCF	Land Use and Land Use Change and Forestry
MESR	Multinomial Endogenous Switching Regression
NCCRS	National Climate Change Response Strategy
NEMA	National Environment Management Authority

PALWECO	Program for Agriculture and Livelihoods in Western Communities
SAPs	Sustainable Agricultural Practices
StARCK+	Strengthening Adaptation and Resilience to Climate Change in Kenya Plus
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Program
UNFCCC	United Nation Framework Convention on Climate Change
UNFPA	United Nations Population Fund
VIF	Variance Inflation Factor

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Climate change is a threat to food security systems and one of biggest challenges in the 21st century (FAO, 2013). It is widely accepted that the ability to contain the pace of climate change by keeping change in temperature rise within 2°C threshold in the long run is now limited and the global population will have to deal with its consequences (IPCC, 2014). Agricultural production systems are expected to produce food for the global population that is expected to reach 9.1 billion people in 2050 and over 10 billion by end of the century (World Bank, 2011). According to Branca *et al*. (2011), agricultural systems need to be transformed to increase the productive capacity and stability of smallholder agricultural production in the wake of climate change. This change has already caused significant impacts on water resources, human health and food security (Turpie *et al*., 2002; Gbetibouo & Hassan, 2005; Kabubo-Mariara & Karanja, 2007; Nhemachena & Hassan, 2007; Deressa *et al*., 2009; Kang *et al*., 2009; Herrero *et al*., 2010; Kabara & Kabubo-Mariara, 2011; Kabubo-Mariara & Kabara, 2015). Rising temperatures and changes in rainfall patterns affect agricultural production with significant decline in crop and livestock production.

Africa has warmed about half a degree over the last century and the average annual temperature is likely to rise by an average of 1.5-4°C by 2099 (IPCC, 2014). World Bank (2010) notes that Africa is becoming the most exposed region in the world to impacts of climate change. It is claimed that sub-Saharan Africa is currently the most food-insecure region in the world (World Bank, 2008). Climate change could aggravate the situation further unless adequate measures are put in place.

According to the Kenya National Climate Change Strategic plan (GOK, 2010), the evidence of climate change in Kenya is unmistakable. Temperatures have risen throughout the country. Rainfall has become irregular and unpredictable, and when it rains, downpour is more intense. Extreme and harsh weather is now a norm in Kenya. More specifically, since the early 1960s, both minimum (night time) and maximum (daytime) temperatures have been on an increasing trend. The minimum temperature has risen generally by 0.7–2.0^{o}C and the maximum by 0.2–1.3^{o}C, depending on the season and the region. GOK (2010) further indicates that these unprecedented changes in climate have accompanied losses that have already been experienced in the country. For instance, evidence indicates that between 1999 and 2000 droughts in Kenya caused damages equivalent to 2.4% of Gross Domestic Product (GDP) (GOK, 2010). Recent study on economic impacts of climate change in Kenya has estimated that annual cost of climate change impacts will be in the tune of USD 1 to 3 billion by the year 2030 (GOK, 2010). According to FICCF (2014), agriculture contributes over 20% of Green House Gases (GHGs) and is the highest emitter. About 90% of the 20% is from livestock production systems.

Strengthening Adaptation and Resilience to Climate Change in Kenya Plus (StARCK+) Programme seeks to address the factors that constrain Kenya's ability to cope with climate change including poverty, weak institutions and under-investment in key sectors. One of the areas of focus is to catalyze private sector innovation and investment to promote innovation and deliver climate resilient and low carbon growth (FICCF, 2014). One way of combatting the effects of climate change in Kenya and other sub-Saharan countries is through Climate Smart Agricultural (CSA) practices (FOA, 2010, 2013; Arslan *et al.,* 2014; Kabubo-Mariara and Kabara, 2015). CSA scoping exercise was undertaken under the StARCK+ Finance Innovation for climate change Fund (FICCF), which aimed at supporting the scale-up of challenging adaptation and mitigation projects using innovative financing instruments. CSA seeks to sustainably increase agricultural productivity and incomes by adapting and building resilience to climate change and reducing and/or removing greenhouse gas emissions relative to conventional practices (FAO, 2013). Climate change has equally been the main cause of decline in agricultural production in western Kenya especially in the parts of Busia leading to high food insecurity.

The achievement of national food security in Kenya is a key objective of the agricultural sector (Kenya Food Security Steering Group, 2008). There has been a general decline in food access in the recent years, and beginning from 2008, the country has been facing severe food insecurity problems. These are depicted by a high proportion of the population having no access to food in the right amounts and quality. Official estimates indicate over 10 million people are food insecure with majority of them living on food relief. Households are also incurring huge food bills due to the high food prices. Maize being staple food due to the food preferences is in short supply leaves many households with limited dietary choices for them (GOK, 2010).

The current food insecurity problems are attributed to several factors, including largely frequent droughts associated with changes in climate patterns in most parts of the country, high costs of domestic food production due to high costs of inputs especially fertilizer, displacement of a large number of farmers in the high potential agricultural areas following the post-election violence which occurred in early 2008, high global food prices and low purchasing power for large proportion of the population due to high level of poverty.

Climate change in Busia County is quite evident with its effects on crops and livestock production significantly experienced (GOK, 2010). It has contributed to high poverty level in Busia County which is currently at 64.2% compared to the national level of 45.9% (Lukano, 2013). The County Government of Busia identifies major effects of climate change as loss of quality and quantity of natural biodiversity, soil erosion and flooding experienced in the southern parts of Teso North Sub-County. Varying rainfall patterns have affected both land preparation and food production leading to lower yields (Lukano, 2013). Similarly, occasional rise in temperature affects moisture retention by soil which leads to wilting of crops hence lower yields contributing to food insecurity. The County Government noted that the long rains' early cessation has led to below average production of both maize and other cereals in the Sub-County. Climate change adaptation is therefore highly necessary to cope with the inherent challenges which are hampering food productivity.

According to FAO (2010), CSA practices are seen as the means to achieve resilience at the same time reducing environmental degradation. The County Government in collaboration with other organizations like ICRAF and NEMA is promoting the implementation of CSA strategies to cope with climate change. The strategies include: agroforestry and carbon trading, awareness creation on rain water harvesting and water management practices. Additionally, methods like crop diversification, adoption of drought/pest resistant crop varieties and seeds, shifting to bio-fuels for domestic and industrial use, sustainable land use, encouraging mitigation through non-forestry activities such as fuel-switching and energy efficiency at the community level and the use of bio-fuels have been largely promoted. Finally, it has enhanced formal, and informal environmental and climate change education, and promotion of agri-business and value addition (Lukano, 2013; FICCF, 2014).

1.2 Statement of the problem

Climate change poses threats to local food production and family wellbeing resulting in malnutrition, hunger, and persistent poverty in Teso north sub-County. CSA is one of the approaches of adapting and coping with the challenges of climate change. It is important because of its triple potential benefits of improved productivity and high income, reduction or removal of greenhouse gases and improved household food security. Although the County government and other stakeholders have promoted a number of CSA practices, some farmers have adopted CSA practices on their farms voluntarily. However, there is a dearth of knowledge on the drivers of the choice and use of the CSA practices and their implication on household food security. Further, farmers may adopt several CSA practices in combinations and it is not clear which of these give the highest payoffs in terms of improved food security. This study was geared towards filling this knowledge gaps by an exploratory study among small scale farmers in Teso North Sub-County.

1.3 Objectives of the study

1.3.1General objective

The general objective of this study was to contribute to improved livelihood of small scale farmers by evaluation of the uptake of Climate Smart Agricultural practices among small scale farmers in Teso North Sub-County.

1.3.2 Specific objectives

1. To identify Climate Smart Agricultural practices used by small scale farmers.
2. To determine the socio-economic, institutional and climate related factors that influence the demand for Climate Smart Agricultural practices.
3. To establish the determinants of choice and effect of Climate Smart Agricultural practices on household food security

1.4 Research questions

1. What Climate Smart Agricultural practices are currently being used by small scale farmers?
2. What socio-economic, institutional and climate related factors influence the demand for Climate Smart Agricultural practices?
3. What are the determinants of choice and effect of Climate Smart Agricultural practices on household food security?

1.5 Justification of the study

The County Government of Busia identifies climate change as one of the major challenges at present time that adds considerable stress in the County (Lukano, 2013). Therefore, the knowledge of institutional and socio-economic factors affecting uptake of CSA is one step towards helping the households achieve an optimal solution in farming practices. This would advance the County's strategic plan by contributing to climate change response leading to improved farmers' resilience and improved food security level.

Furthermore, the results will be used to provide reference for better understanding of the importance of practicing CSA by farmers. This will further help to inform policy makers and program designers on climate change response of agricultural systems in County Government of Busia and the National Government as well.

1.6 Scope and limitation of the study

This study was carried out in Teso North Sub-County targeting small scale farmers living and practicing farm production. It captured information regarding the previous main production season. Further, socio-economic, institutional and climate related factors were sought to establish how they influence usage of CSAs and food security status of farmers.

This study was limited to household and farm level analysis. Seasonal variation in food production was not considered yet may influence food availability.

1.7 Operational definition of terms

Climate change: refers to natural and or human induced changes in the mean and/or the variability of climate properties and that persists for an extended period, typically decades or longer (IPCC, 2007).

Climate change adaptation: refers to adjustments in ecological-social-economic systems in response to actual or expected climatic stimuli, their effects or impacts (IPCC, 2001; Smit & Olga, 2001).

Climate Smart Agricultural practices: FAO Defined CSA as agricultural activity that is: sustainably and efficiently increases productivity and incomes (adaptation), reduces or removes Greenhouse gases emissions (mitigation), enhances achievement of national food security and development goals (FAO, 2010).

Climate Smart Agricultural strategies: a group of related (in terms of use) climate smart agricultural practices.

Climate Smart Agricultural packages: a combination of climate smart agricultural strategies used by farmers in the study area.

Vulnerability: vulnerability is portrayed as having "an external dimension, which is represented by the 'exposure' of a system to climate change variations, as well as an internal dimension, which comprises it's 'sensitivity and its adaptive capacity" to these stressors' (Füssel & Klein, 2006).

Small scale farmers: are farmers who own 5 acres or less living and practicing farming in Teso North Sub-County

Food security: refers to access by all people in a socially acceptable means at all times to nutritionally adequate and safe food for an active and a healthy life (Bickel *et al*., 2000).

CHAPTER TWO

LITERATURE REVIEW

In this section, literature of past studies on climate change, its impact on agricultural production, the concept of Climate Smart Agriculture and its potential contribution to farmers' food security status were reviewed. Furthermore possible socio-economic and institutional factors were investigated to understand their influence on the use of CSA climate change coping strategy. The reviews led to identification of the knowledge gaps in existing literature which this study sought to bridge. Finally, a random utility maximization theory on which this study was anchored was reviewed and a conceptual framework presented.

2.1 The concept of climate change

The origin of climate change debate can be traced back to the early1980 as an international environmental and developmental challenge beginning with the publication of the Brundtland Report in 1987. Two years later, the Intergovernmental Panel on climate change (IPCC) was formed to provide reports on climate change. Then in 1992 during the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, the United Nations Framework Convention on Climate Change (UNFCCC) was established. Since then, there have been a series of Conference of the Parties (COP) to UNFCCC, which have produced 'Accords and Protocols' including Marrakesh Accords, Kyoto Protocol and the Copenhagen Accord (Smit *et al.*, 1996; IPCC, 2001; Smit & Olga, 2001; GOK, 2010; UNFCCC, 2015; UNFCCC, 2016). Key issues that have continued to shape the global climate change regime are also explained in the conference of parties (COPs). Such issues tackled include climate change mitigation, adaptation, finance, technology development and transfer, governance as well as the role of land-use and land-use change and forestry (LULUCF) in climate change mitigation especially in developing countries.

2.2 Climate change response and agricultural adaptation

Global humanity has endeavored to respond to climate change through adjustments in ecological-social-economic systems to actual or expected climatic stimuli, their effects or impacts (IPCC, 2001; Smit & Olga, 2001). The goal of climate change response is centered on building resilience of communities towards different kinds of changes in their environment. Resilience is the capacity to maintain competent functioning in the face of major life stressors (Adger, 2001). When a social or ecological entity loses resilience, it becomes more vulnerable to changes that previously could be absorbed and adapted to (Eriksen & Kelly, 2004).

In the sphere of climate change response, adaptation and coping are terms used sometimes interchangeably but could imply different meanings. However, the two are associated with different time scales and represent different processes (Eriksen & Kelly, 2004). Whereas, coping is short term reactive response to climate change variability, adaptation is associated with longer time scales and points at adjustments as fundamental changes of the systems' practices, processes or structures due to changes in mean conditions of the surrounding environment. With adaptations, new coping range is established (Smit & Wandel, 2006). Nonetheless, coping strategies may become adaptive strategies when people are forced to use them over a run of bad years and across seasons rather than just at the worst time of the year (Anderson *et al*., 2010).

IPCC (2007) recognizes three types of adaptation: First, autonomous, or spontaneous adaptations which are unconscious and reactive response to climatic stimuli without intervention with a public policy. The second one is called anticipatory/proactive which refers to adaptation that takes place before the impacts of climate change occur. The third and final is planned adaptation which is based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state. Whereas planned adaptations are interventional strategies, autonomous adaptations occur naturally without interventions by public agencies (Smit *et al.,* 1996). Agricultural adaptation is important in the wake of climate change impacts to achieve food security in the global community. Studies indicate that adaptation can lessen the yield losses that might result from climate change, or improve yields where climate change is beneficial (Adams *et al.,* 1998).

According to Okumu (2013), although relatively inexpensive adaptation strategies such as crop diversification and changing the timing of farm operations, may moderate adverse impacts, the biggest benefits will result from more costly measures including institutional strengthening and technological developments. These adaptation measures, alongside other competing interests, will require substantial resource allocation by farmers, national and County governments, scientists and development partners.

2.3 Impact of climate change on agricultural production

Climate change projections in relation to future rainfall, floods and drought are uncertain (Okumu, 2013). However, temperature projections are generally reliable. General warning of global warming in Sub-Saharan Africa is projected to be larger than the global annual average (IPCC, 2007). As regarding temperature, increased temperature levels will cause additional soil moisture deficits, crop damage and crop diseases; unpredictable and more intense rainfall; and higher frequency and severity of extreme climatic events (Boruru *et al*., 2011). Similarly, the drivers of climate change have the potential of altering plant growth and harvestable yield through carbon dioxide fertilization effects (UNDP, 2012). Free Air Carbon Enrichment (FACE) experiments indicate productivity increases in a range of 15–25% for crops like (wheat, rice and soya beans) and 5–10% for crops like (maize, sorghum and sugarcane). Higher levels of CO_2 also improve water use efficiency of both categories of plants (Lotze *et al*., 2009).

According to FAO (2011) temperature rise has significant effect on pollination services. In the tropics, most pollinators are already living close to their optimal range of temperature tolerance. However, temperatures are expected to increase from 1.1 to 6.4 in the course of 21st century. Hence, climate change will have detrimental effects on pollination. The global monetary value of this service has been estimated to US$ 24 billion per year. CSA implemented on landscape level can help protect this vital ecosystem service by building agro-ecosystem's resilience.

2.4 The concept of climate smart agriculture

The concept of Climate Smart Agriculture was first presented in FAO meeting at the Hague conference on Food security and climate change in 2010. FAO defined CSA as agricultural activity that: Sustainably and efficiently increases productivity and incomes (adaptation), reduces or removes Greenhouse Gases (mitigation) and enhances achievement of national food security and development goals (FAO, 2010). This concept was generally meant to strike a balance between food production and environmental stability without compromising any of the two.

The connection between agriculture and climate change is real and potentially deadly. On one hand, the agricultural value chain, and land use change, including deforestation account for 30% of the total global GHG emissions; while on the other hand, the adverse impacts of climate change are leading to land degradation, and food insecurity (IPCC, 2007). Livelihood security requires more resilient production systems. Similarly, more productive and resilient agriculture requires management of natural and environmental resources (FAO, 2010). Transiting to such systems could generate significant mitigation benefits (FAO, 2010; World Bank, 2011). CSA seeks to increase productivity in an environmentally and socially sustainable way, to strengthen farmers' resilience to climate change, and to reduce agriculture's contribution to climate change by reducing GHG emission and increasing soil carbon sequestration (FAO, 2010; World Bank, 2011).

2.4.1 What is new with CSA?

Plate 1: Conservation agriculture

Source: Adapted from FAO 2010

As presented in Plate 1, CSA is not a new agricultural system nor is it a new set of approaches. It is rather an approach, away to guide the needed changes in agricultural systems given the necessity to jointly address food security and climate change (FAO, 2013). CSA shares Sustainable Development and Green Economy objectives and guiding principles as it also aims for food security and preservation of the natural resources. FAO (2013) further notes that CSA takes into account the four dimensions of food security in terms of availability, accessibility, utilization and stability. Still, the entry point and the emphasis is on production, farmers, increasing productivity and income, and ensuring their stability.

Climate-smart measures includes proven techniques such as mulching, intercropping, integrated pest and disease management, minimum soil disturbance practices (MSD), crop rotation, agroforestry, integrated crop-livestock management, aquaculture, improved water management, better weather forecasting for farmers and innovative practices, such as early warning systems (FAO, 2010; World Bank, 2011; 2012). It also entails embracing new technologies such as diversifying genetic traits of crops to help farmers edge against an uncertain climate and creating an enabling policy environment for adaptation (World Bank, 2011). Further still, CSA is concerned with post-harvest handling of crop produce along the value chain to minimize losses as well as the sustainable consumption patterns. In the absence of Climate Smart Agriculture, marginal areas may become less suited for arable farming as a result of land degradation through deforestation, soil erosion, repetitive tillage and overgrazing (World Bank, 2012). However, there is recognition that Climate Smart efforts must have at their heart smallholder farmer in the developing nation who is key to change across the entire agricultural system. Policy accompaniment and financing of the agricultural practices is yet another inclusion in the general scope of the original concept of CSA (FAO, 2013).

2.4.2 CSA developments in Kenya

The Finance Innovation for climate change Fund (FICCF), which is funded by the Department for International Development (DFID), commissioned a scoping study between May and June 2014 to develop an overview of the current initiatives and efforts taking place in CSA in the non-ASAL areas of Kenya (FICCF, 2014). The study was conducted to develop the CSA component of the FICCF, which is one component of the StARCK+ programme. The major objective of FICCF CSA initiative was to support low carbon, climate change resilient, efficient, productive and sustainable smallholder agriculture and to facilitate scaling up/out investments in promising CSA initiatives. The results identified climate smart aspects of the value chains of maize/legumes, sorghum, cassava, dairy, indigenous chicken and tilapia fish. The analysis targeted links, weaknesses or failures that exist in those value chains, and are not the focus of other interventions. Using farmer group leaders in 22 non ASAL counties of Kenya, views on various climate change adaptation strategies were fetched as follows:

Reliability of weather forecast was noted as the way to improve the ability of farmers and the government to know in advance whether seasonal rainfall amount could help them choose the right crops varieties, adjust their cropping practices or take other necessary measures like soil and water conservation strategies to maximize benefits or minimize losses as explained by Rao *et al.* (2005); seasonal forecasting can significantly reduce these uncertainties; a strategic partnership of farmers with Kenya Meteorological Department (KMD) and the extension service actors to forecast, package and disseminate agro weather forecasts to target farmers is necessary (FICCF, 2014).

Most notably, there is a clear need to develop, test and release new crop varieties and livestock breeds that would be adapted to the changing climatic and ecological conditions of Sub-Saharan Africa. New crop varieties as noted by Travis *et al.* (2010) could lead to less intensive use of other inputs such as fertilizer and pesticides. Crop varieties and livestock breeds that are resistant to drought, pests and diseases will improve smallholder farmer's ability to adapt to climate change. According to the findings of the FICCF study, most importantly also branding of less utilized adaptive crops (such as sorghum and cassava) to major staple crop level appeared as a recommendation by interviewed stakeholders.

Soil and water conservation techniques such as terracing and mulching also emerged as another area of concern., can significantly improve the water holding capacity of soils and mitigate the negative effects of dry spells (Oloo, 2013. Conservation tillage has the potential to improve soil fertility, reduce erosion and enhance the water use efficiency of crops as explained by Kaumbutho *et al*. (1999). FAO (2013) explained that conservation tillage, for instance, is a useful strategy for improving the storage of rain water in the soil and can help mitigate agricultural drought. FOA (2013) enhancing supply includes; increased access to and improved management of conventional water resources, habitat rehabilitation, dam operations, re-use of drainage water and waste water, transfer of water between river basins, desalinization, and pollution control. On the demand side, a set of actions should be placed to regulate the demand if water either by raising the economic efficiency of water use as a natural resource, or operating reallocation of water resources. Technical, managerial, legal investments strategies are needed to help farmers produce more with less water.

Finally, agroforestry is another key area of climate change mitigation that was highly pronounced in the stakeholders' meeting**.** Sanchez (2000) noted that agroforestry is emerging as a promising climate change adaptation strategy to improve and sustain agricultural productivity and also to enhance rural income. Growing multipurpose tree and shrub species with crops and/or animals can provide additional benefits, like fodder for animals and wind breaks. Kwesiga *et al*. (2003) explained that products and services provided by agroforestry include improvement of soil fertility, provision of animal fodder; creation of a favorable micro-climate for crops, reducing temperature stress; provision of fruits and wood for fuel and construction. In agroforestry systems, fast growing leguminous trees or shrubs are rotated with maize to improve yields of the cereal crops.

2.4.3 How can CSA address food security?

The concept of food security has been used extensively at the household level as a measure of welfare. A household is considered food secure if all members at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Climate change disrupts food markets, posing population wide risks to food supply. Increasing the adaptive capacity of farmers as well as increasing resilience and resource use efficiency in agricultural production systems is paramount (FAO 2013). Indeed climate change alters agricultural production and food systems, and thus the approach to transforming agricultural systems to support global food security and poverty reduction is through CSA.

CSA prioritizes food security with a consideration of mitigating climate change (Lipper *et al*. 2014). Food security in an era of climate change may be possible if farmers transform agricultural systems by use of means such as improved crop seed and fertilizer (Bryan *et al*. 2011). An integrated, evidence based and transformative approach to addressing food and climate security at all levels is required. It calls for a coordinated action from the global to local levels, from research to policies and investments, and across private, public and civil society sectors to achieve the scale and rate of change required.

Through Climate Smart practices, more efficient resource use agricultural production systems offer considerable potential for increasing agricultural productivity, incomes, food security and the resilience of rural livelihoods while reducing the intensity of agricultural emissions (FAO, 2010). With the right practices, policies and investments, the agriculture sector can move into CSA pathways, resulting in decreased food insecurity and poverty in the short term while contributing to reducing climate change as a threat to food security over the longer term.

2.5 Methods of measuring household food security

2.5.1 Expenditure and income surveys

Households are asked to give information on expenditure made on various food commodities consumed. The information may cover weeks or months prior to the time of the survey (Townsend *et al*., 2001). Households are asked to state the quantities of food bought and the associated costs, foods received as gifts or payments in kind, and foods grown by the household for consumption. Advantages of this method include: the cause of food insecurity can be determined, information on dietary quality is also collected and it can be used to examine the national nutritional situation for establishment of food security programs. The biggest disadvantage of this method is that it measures the amount of food available but not the actual amount consumed. Again, the method is costly and requires interdisciplinary expertise to conduct the survey.

2.5.2 Anthropometry

Food consumption is measured based on considerations of size, weight, body proportions and ultimately the composition of the human body. Food insecurity and the health status of the individual are measured at the same time. The anthropometric indicators most commonly used in national surveys are based on weight and height (or length) of infants, young children, youth and adults. The interpretation of the adequacy of the anthropometric indicators is based on well-established cut-off points (Radimer, 2002). The advantage of this method is that weight and height measurements are highly standardized and are highly reproducible across individuals doing the anthropometry and across settings Webb *et al.*, 2006). Anthropometry also allows for mapping nutritional security from the local to the national level and for understanding trends, determinants and consequences of malnutrition at the individual level. The disadvantage of this method is that it requires skilled expertise. Secondly, the interpretation of the relationship between food insecurity and obesity is complex, as there is growing evidence that whereas severe food insecurity leads to wasting, mild to moderate food insecurity may lead to obesity.

2.5.3 Food insecurity experience-based measurement scales

This method measures the experiences of food insecurity of a household/individual over a particular time frame. It was established by researchers from Cornell and Tufts Universities in the United States of America (USA) and by a non-governmental organization (Townsend *et al*., 2001). A ten item scale covering psycho-emotional, dietary quality, and dietary quantity was developed. The Cornell scale focuses on lack of access to nutritional foods or enough amounts of foods because of lack of money. Questions are usually answered by a respondent who is in charge or well informed about food acquisition and food intake patterns in the household. An algorithm based on the questions that are answered affirmatively (i.e., describing experiencing the negative situation sometimes or frequently) was developed to classify the household as either food secure or as food insecure with or without hunger (Radimer, 2002).

2.5.4 Household's dietary intake

This is the most commonly used method which measures food security by applying a 24 hour or weekly recall basis (WFP, 2009). Households will be required to keep records or recall the foods consumed within the last 24 hours or seven days. This method is advantageous as it measures the food availability, access and actual consumption/utilisation, three key aspects of food security. This method also addresses the caloric and dietary quality concerns using food frequency questionnaire. The only disadvantage of this method is that where memory is relied on, could lead to substantial bias as some information may be lost. Again, periodic variability of food availability may not be captured using this method.

2.6 Factors influencing adoption of CSA strategies

Socio-economic factors that influence adoption of adaptation strategies include household characteristics and farm characteristics. The household characteristics that can potentially influence adoption decisions include age, education level, gender of the head of the household, household size, years of farming experience, attitude towards risk and wealth. The age of a farmer may positively or negatively influence the decision to adopt new technologies (Gbegeh & Akubuilo, 2013). Older farmers have more experience in farming and are better able to assess the characteristics of modern technology than younger farmers, and hence a higher likelihood of adopting the practice. On the other hand, older farmers are more risk-averse and less likely to be flexible than younger farmers and thus have a lesser likelihood of adopting new technologies (Adesina & Forson, 1995). According to Ayuya *et al*. (2012) attitude towards risk both influence the decision on willingness to accept and the extent of adoption. The explanation is that farmers who are risk taking would be willing to adopt the project to a larger extent than those who are risk averse.

Education level is often assumed to increase the likelihood of embracing new technologies as it enhances the famer's ability to recognize the effects of climate change (Nkonya *et al.,* 2008). Similarly, education enables households to access and conceptualize information relevant to making innovative decisions (Adesina & Forson 1995; Owuor & Bebe, 2012). However, higher educational attainment can present a constraint to adoption because it offers alternative livelihood strategies, which may compete with agricultural production.

The effect of gender of household head on adoption decisions is location-specific culture driven (Gbetibouo, 2009). In many parts of Africa, women are often deprived of property rights due to social barriers (Gbegeh & Akubuilo, 2012). Consequently, they have fewer capabilities and resources than men (De Groote & Coulibaly, 1998; Marenya & Barrett, 2002). However, female-headed households are more likely to take up climate change adaptation measures (Nhemachena & Hassan, 2007; Gbetibouo, 2009). The possible reason for this observation is that in most rural smallholder farming communities in Africa, more women than men live in rural areas where much of the agricultural work is done. Therefore, women have more farming experience and information on various management practices and how to change them, based on available information on climatic conditions and other factors such as markets and food needs of the households (Nhemachena & Hassan, 2007). Farmer's wealth has a significant influence on ability of smallholder farmers to adopt certain technological practices (Nkonya *et al*., 2008; Gbetibouo, 2009). Households with higher income and greater assets like land and other valuable movable assets are less risk averse than lower income households, and therefore are better placed to adopt new farming technologies (Shiferaw & Holden, 1998).

The influence of household size on the decision to adopt new farming techniques in response to climate change is uncertain. Household size as a proxy to labor availability may influence the adoption of a new technology positively as its availability reduces the labor constraints (Marenya and Barrett, 2007; Teklewold *et al*., 2013). Given that the bulk of labor for most farm operations in Sub-Saharan Africa is provided by the family rather than hired, lack of adequate family labor accompanied by inability to hire labor can seriously constrain adoption practices (Nkonya *et al*., 2008). Nonetheless, households with many family members may be forced to divert part of the labor force to off-farm activities in an attempt to earn income to ease the consumption burden imposed by larger household size (Tizale, 2007; Gbetibouo, 2009). Farm characteristics could also influence adoption decisions and they include farm size and soil fertility, soil erosion and slope of land. Farm size influences both the access to information and the adoption decisions (Marenya & Barrett, 2007; Gbetibouo, 2009). Soil fertility may influence adoption of recovery practices. Sloppy Terrain may influence soil erosion and hence adoption of recovery measures.

On the other hand, institutional factors could also influence adoption of new technologies and they include; access to credit, access to information, off-farm employment, land ownership, group membership and government policies (Adesina & Forson, 1995; Gbetibouo, 2009). Adoption of new farming strategies require funds and lack of borrowing capacity may limit ability of farmers to embrace adaptation measures that require heavy investment for instance in strategies such as irrigation, terracing, tree planting soil testing and fertilizer use (Gbetibouo, 2009). Access to information may influence farmers' decision to adopt new technologies as they were made aware about its existence. Similarly, farmer to farmer extension and information sharing about future climate change may enable them to adjust their farming practices in response to climate change (Smit *et al*., 2001; Mariara & Karanja 2007; Gbetibouo, 2009).

Land ownership has an implication on the property rights and long term investment in climate change adaptation strategies. For instance, tenure security can contribute to adoption of technologies linked to land such as irrigation equipment or soil conservation practices. Farmers lack economic incentives to invest their time or money if they cannot capture the full benefits of their investments (Gbetibouo, 2009; Shiferaw *et al*., 2009). Off-farm employment may provide alternative sources of income to the household hence limiting dependence on agriculture and may further lower the chances of climate change adaptation. Farmer groups also may serve sometimes as the means through which farmer training and information dissemination can take place. Government extension service officers target farmer groups for demonstration of new technology. Finally, government policy on climate change could set conditions for agricultural operations to be observed as a rule. Hence farmers may be mandated to perform conservation agriculture within the legal framework (Smit *et al*., 2001; Mariara & Karanja 2007; Gbetibouo, 2009).

2.7 Gaps in literature review

A wide variety of literature covers the possible impacts of climate change on agricultural production and ways of adapting to climate change (Adams *et al.*, 1998; IPCC, 2007; Boruru, *et al.*, 2011; Okumu (2013). These studies generally indicate that farmers can overcome the adverse impact of climate change by implementing adaptation measures. Much of the literature review on agricultural adaptation to climate change has drawn attention to a range of factors affecting the adoption of such methods by small-scale farmers. A lot of these studies merely identify household, farm characteristics and institutional factors as the key determinants of adoption (Adesina & Forson, 1995; Maddison, 2006; Marenya & Barrett, 2007; Nkonya *et al.*, 2008; Gbetibouo, 2009; Shiferaw *et al*., 2009; Ayuya *et al*., 2012; Ochieng *et al*., 2012). However, there is a dearth of information on the drivers of choice and impact of specific CSA practices on household food security status of small scale farmers.

The FICCF scoping study was generally done at the national level targeting major stakeholders in workshops (FICCF, 2014). The study was done to identify CSA interventions that contribute or could contribute to increased or sustained production of agricultural production systems amidst climate change and provide recommendations to FICCF on the most appropriate interventions for the period 2014-2017 for increasing farmer's access to finance from micro-finance institutions to address those gaps in the value chain. As presented in the report, this study did not target households at grassroots for survey. Further still, the study did not assess the impact of CSA practices on household food security status. This study was therefore focused on undertaking a household and farm level analysis on the effect of CSA practices on food security status of farmers to bridging the gap.

2.8 Theoretical and conceptual framework

2.8.1 Theoretical framework

This study was guided by the random utility maximization theory under the assumption that farmers choose a particular climate change response strategy depending on the level of utility generated. According to this theory, the choice of a particular CSA package is guided by random factors (McFadden, 1973). The utility of a choice is comprised of deterministic and an error component. The error component is independent of the deterministic part and follows a predetermined distribution. This shows that it is not usually possible to predict with certainty the alternative that the decision-maker will select. However, it is possible to express probability that the perceived utility associated with a particular strategy is greater than other available alternatives (Cascetta, 2009).

The U utility that individual m gains from the consumption of a good n is made up of an observable deterministic component V (the utility function) and a random component $\mathcal{E}$, and can therefore be defined as follows:

$$U_{mn} = V_{mn} + \varepsilon_{mn} \quad (1)$$

Cascetta (2009) explains that, we assume that utility Udepends on choices made from some set of n (CSA) strategies. The individual is assumed to have a utility function of the form:

$$U_{mn} = V(X_m, Z_n) \quad (2)$$

X_m is CSA attributes while Z_n farmers attributes. A rational farmer who seeks to maximize the present value of benefits (food security) of production over a specified period of time must choose among a set of n CSA strategies. The farmer will use CSA strategy n if the perceived benefit from that strategy is greater than the utility from other strategy q if $U_n > U_q$. Utility derived from any CSA strategy is assumed to depend on the attributes of the CSA strategy itself and the socio-economic characteristics of the farmer (Cascetta, 2009). However, a farmer may not choose what seems to be the preferred CSA strategy. To explain such variations in choice, a random element $\mathcal{E}$, is included as a component of utility function. Equation 2 can then be re-written as:

$$U_{mn} = V(X_n, Z_m) + \varepsilon(X_n, Z_m) \quad (3)$$

The probability that farmer m will choose CSA strategy n among the set of CSA strategies q could be defined as follows:

$$P[m(CS)] = P[U_n > U_q], \qquad n \in CS \quad (4)$$

$$= P[(V_n + \varepsilon_n) > (V_q + \varepsilon_q)]$$

$$P[(V_n - V_q) > \mu]$$

Where CS is the complete choice set of CSA practices. In order to estimate equation 4, assumptions must be made over the distributions of the error terms. A typical assumption is that the errors are Gumbel-distributed (maximized error terms) and independently and identically distributed (same probability distribution and mutually independent) (McFadden, 1973).

2.8.2 Conceptual framework

Figure 2 shows the conceptual framework which depicts links between climate change shocks (bad incidents), CSA practices, climate change resilience and improved food security. Institutional and socio-economic factors are intervening in the framework to influence the adoption of the CSA practices. CSA is indicated as a responsive measure to climate change impacts which includes both proactive and planned adaptation measures. Well instituted CSA improves resilience, crop and livestock yields. Improvement in yields leads to higher incomes. Higher incomes lead to improved food security at four levels (availability, accessibility, utilization and stability). CSA practice apart from improving resilience of agricultural systems can also reduce GHG emission climate change impacts.

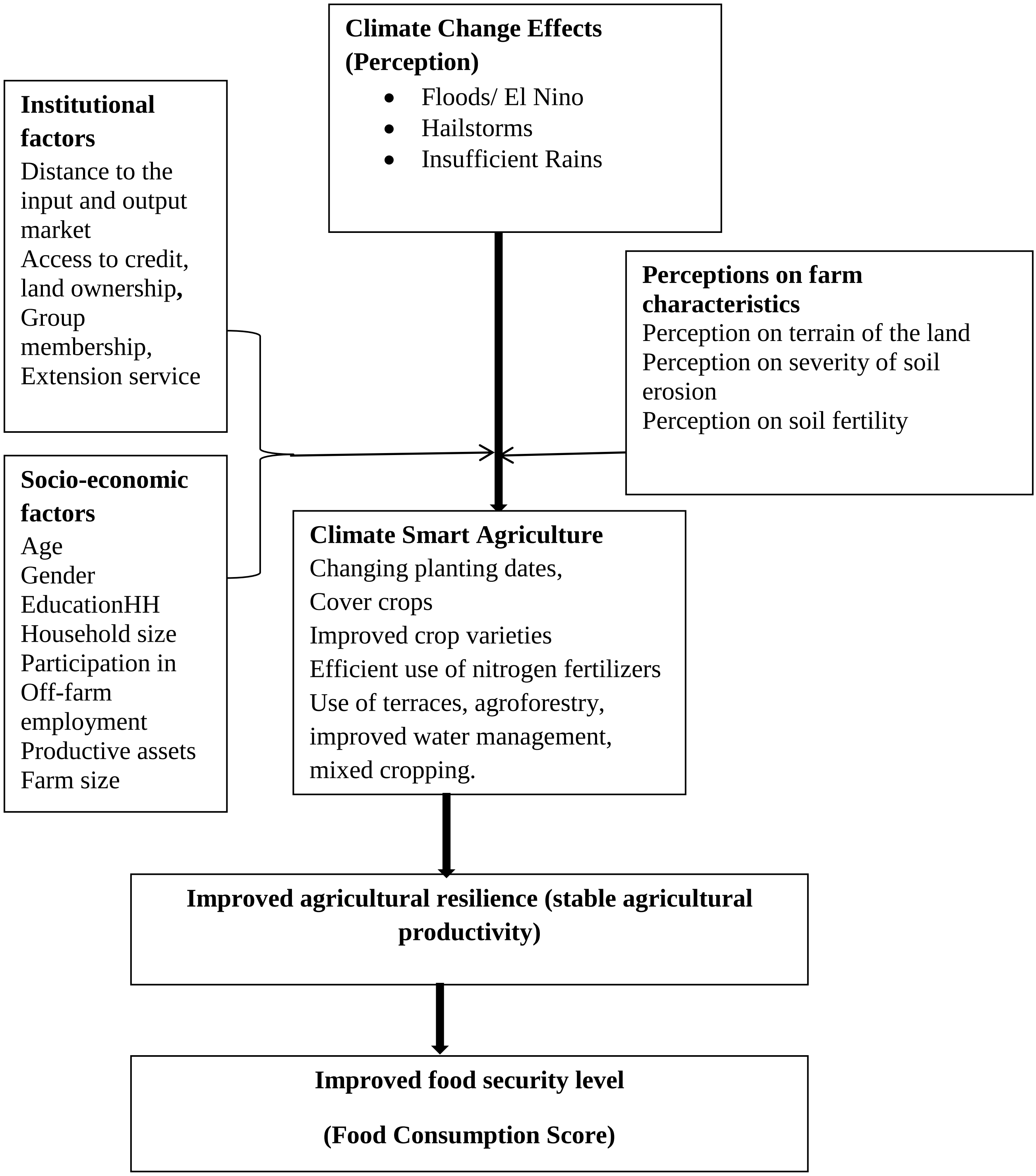

Figure 2: Conceptual framework

CHAPTER THREE

METHODOLOGY

3.1 The study area

This study was conducted in Teso North Sub-County, Busia County. This area was selected for study because of its high potential for food production in the entire Busia County attributed to its better soils. It lies on the Northern part of Busia County and has six wards (Malaba Central, Malaba South, Malaba North, Ang'urai South, Ang'urai North, and Ang'urai East) and covers an area of 261 Km^2 with a population of 117947 (Lukano, 2013). The region is about 438 kilometres (272 miles) northwest of Nairobi city. The coordinates of Malaba town, the capital of the Teso North Sub-County Kenya are: 0°38'07.0"N, 34°16'31.0"E (Latitude: 0.635278; Longitude: 34.275278). The town sits at an altitude of 3,871 feet (1,180 m), above sea level (KIG, 2016). The Sub-County has two main rivers Malakisi and Malaba on the Northern part. The dry season with scattered rains falls from December to February. The Sub-County receives an annual rainfall of between 760mm and 2000 mm. Lukano (2013), indicates that 50% of the rainfall falls in the long rain season which is at its peak between late March and late May, while 25% falls during the short rains between August and October. The annual mean maximum and minimum temperatures range between 26°C-30°C and 14°C-22°C respectively.

Teso North Sub-County has mainly sandy loam and dark clay soils suitable for cotton, tobacco, maize, Robusta coffee and sugar cane cultivation hence, this Sub-County is the food basket of the Busia County. However, the main crops grown in the Sub-County include: maize, cassava, finger millet, beans, sorghum, sweet potatoes, cowpeas, groundnuts, bananas, green grams, sesame, soya beans, cotton, tobacco, sugarcane, oil palm, and pepper. There are also horticultural crops including pineapples, tomatoes, kales, cabbages, water melons, local vegetables, papaya, amaranth, onions and, mangoes, among others. The main livestock in the County are zebu cattle, sheep, goats, pigs and free-range local chicken (Lukano, 2013).

The sub-County has experienced environmental degradation including loss of quality and quantity of natural biodiversity, soil erosion and flooding which poses threat to its food production potential. Varying rainfall patterns have affected both land preparation and good production leading to lower yields. There is a remarkable decline in water volumes in rivers, wells, pans, and springs with the average distance to watering point averaging at 1.5 km. The map of the study area is as shown in Figure 3.

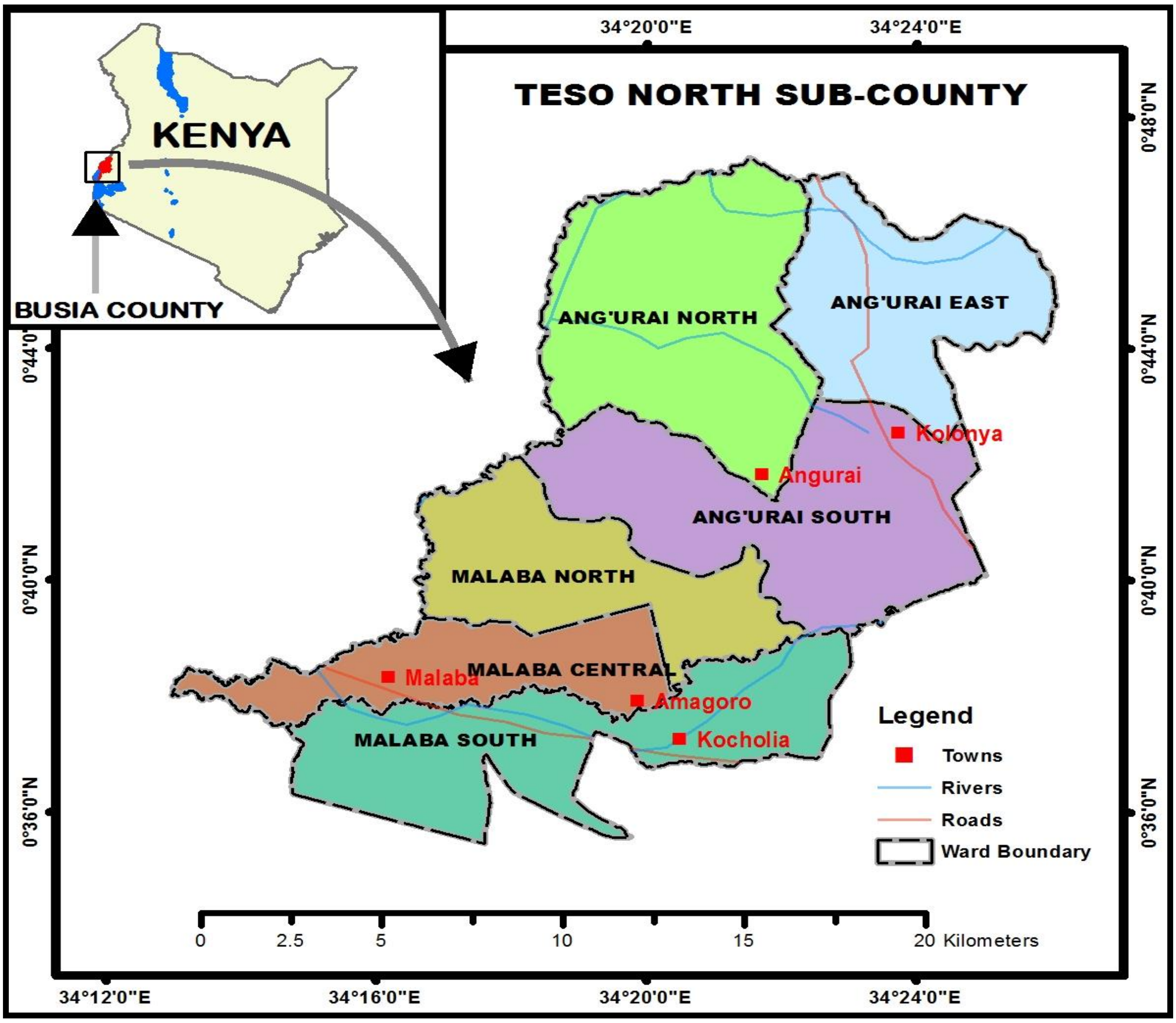

Figure 3: Map of Teso North Sub-County

Source: World Resource Center, 2016

3.2 Sampling technique

The population of the study consisted of all small scale farmers in Teso North Sub-County. Multistage sampling procedure was employed to select respondents whereby in stage one; Teso North Sub-County was purposively selected based on its high food production potential in the entire Busia County. In stage two, three wards (Malaba South, Malaba North and Ang'urai South) were randomly selected from the six wards in Teso North Sub-County. Finally in the last stage, simple random sampling was used to select 384 farmers for interview from a source list acquired from the office of County Director of Veterinary services.

3.3 Determination of the sample size

Determination of the sample size was based on the formula given by Kothari (2004) as shown below:

$$n = \frac{pqz^2}{E^2} \quad (5)$$

Where; n is the sample size, z is confidence level ($\alpha = 0.05$), p was the proportion of the population of interest, smallholder farmers in the study area. Variable q was the weighting variable and it was computed as ($1-p$) and E was an acceptable error (level of precision). p was 0.5 since statistically, a proportion of 0.5 results in a sufficient and reliable size particularly when the population proportion is not known with certainty. This led to q of 0.5 (1- 0.5). An error of less than 10% is usually acceptable according to (Kothari, 2004). Thus, an error of 0.05 was used to approximate a sample size of 384 respondents.

3.4 Data collection and analysis

Primary data was collected by use of interview schedules. The schedules were used in the individual interviews administered by trained enumerators. A pilot study was conducted to test the validity of the questionnaire. Farmers were asked to state various CSA practices they employ as response to climate change. Further, they were also asked to state any past experiences of bad weather. Respondents were also required to fill both one day and seven day food consumption schedules as indicated in Appendix I section C. The data collected were analyzed by use of STATA and SPSS computer programs.

3.5 Methods of analysis

Objective one: To identify CSA strategies used in Teso North Sub-County.

CSA practices used in Teso North were identified and grouped into heterogeneous principal clusters by use of principal component analysis. Homogenous practices were grouped into four composite clusters. With minimal additional effort, PCA provides a roadmap for how to reduce a complex data set to a lower dimension to reveal the sometimes hidden, simplified dynamics that often underlie it (Shlens, 2003). Observed and unobserved factors influencing choice of a particular practice were combined to come up with clusters. The practices were grouped using principal component analysis with iteration and varimax rotation in the model represented as shown below:

$$Y_1 = a_{11}x_{12} + a_{12}x_2 + \dots\dots\dots\dots + a_{1n}x_n \quad (6)$$

. .

. .

$$Y_j = a_{j1}x_{j1} + a_{j2}x_2 + ... + a_{jn}x_n$$

Where Y_1,……………………....Y_j = principal components which are uncorrelated

a_1 - a_n = correlation coefficient

X_1,…….X_j, = factors influencing choice of a particular strategy. The CSA practices identified and grouped through a Principal Component Analysis are Table 1. Selection of these practices was guided by the successful CSA practices established by a previous study done by Forum for Agricultural Research in Africa in the region (FARA, 2015).

Table 1: Climate Smart Agricultural practices identified to be actively used by farmers

S/N	CSA practices
1	Use of improved crop varieties
2	Use of legumes in crop rotation
3	Use of cover crops
4	Changing planting dates
5	Efficient use of Nitrogen fertilizers
6	Use of terraces
7	Planting trees on crop land
8	Use of live barriers
9	Diversified crop and animal breeds
10	Irrigation
11	Use of improved livestock breeds
12	Use of organic fertilizers
13	Planting crops on tree land
14	Use of mulching

Objective two: Modeling the socio-economic, institutional and climate related factors influencing demand (use) of CSA response strategies.

The demand for CSA was measured by the number of CSA practices (components generated in the previous section) used by a farmer. Most commonly applied econometric models for instance Multiple Linear regression, do not allow for effective quantification of relationship between socioeconomic and institutional variables and technology adoption when the dependent variable is discrete (Octavio *et al*., 2000). According to Judge *et al.* (1985) and Octavio *et al*. (2000), researchers sometimes artificially lump adoption levels into two categories (1 for full adoption and 0 for no adoption) in order to use Binomial Probit or Logit models, this unfortunately induces statistically undesirable measurement errors. Previous studies by Ganguly *et al*. (2010) and Gido *et al.* (2015) argue that the use of Tobit or

Ordinary Least Square regression models when the dependent variable is a non-negative integer produces biased results. This is especially experienced in the developing countries as small scale farmers adopt technologies sequentially (Ramirez & Shultz, 2000).

To address this challenge count models were used to analyze adoption of several techniques/technologies. The number of CSA (components) strategies adopted by a farmer represents a count data and thus, count models would be appropriate in this study. Therefore, Poison Regression Model (PRM) was used to determine factors influencing demand for CSA practices used by small scale farmers as it allows quantification of the relationship between socio-economic and institutional factors influencing use of a particular technology when it is a count data. The assumption that famers chose a particular number of packages that gives them higher utility. According to Park & Lohr (2005), utility derived from a particular package depends on, F a vector for observed farm factors and R a vector for household characteristics as shown below:

$$U_{ij} = \gamma_j (F_i, R_i) + \varepsilon_{ij} \quad j = 0,1,2,..........m; \quad i = 1,2,.....n \tag{7}$$

j indicates the number of practices adopted by the i^{th} farmer while γ is a vector of conformable parameters to be estimated and ε_{ij} is the error term. The i^{th} farmer adopts $j = 1$ or more if $U_{ij} > U_{0i}$.The number of CSA strategies adopted by farmers can therefore be expressed as follows:

$$prob(Y_i = j) = \frac{e^{-\lambda_i} \lambda^{ij}}{j!}, \qquad j = 0,1,......m; \quad i = 1,2,.........., n. \tag{8}$$

λ_i is both the conditional mean and variance of the Poisson distribution and m is the maximum number of CSA strategies adopted. The mean number of CSA strategies adopted and its variance is given by:

$$E(Y_i) = Var(Y_i) = \lambda_i = e^{\beta'(F,R)} \; (i = 1,2,....n) \tag{9}$$

$E(Y_i)$ Is the mean value of the dependent variable for the i^{th} farmer, β is a vector of unknown parameters, n is the number of farmers. PRM requires that the mean and variance be equal if not overdispersion or underdispersion is present hence it fails to give appropriate results. In such case then Negative Binomial Regression (NBR) model is recommended as the alternative whereby:

$$Var(Y_i) = \lambda_i + \alpha \lambda_i^2 \tag{10}$$

α is the dispersion parameter whereby if $\alpha = 0$ then NBR=PRM and PRM becomes a special case of NBR (Green, 2002).

Objective three: Modeling the determinants of choice and effect of Climate Smart Agricultural practices on household food security

A two stage multinomial endogenous switching regression (MNLESR) model was used to model the determinants of choice and effect of CSA practices on food security of small scale farmers. Household Food Consumption Score was used as a proxy for food security (Bickel *et al.*, 2000). In the first stage, farm households were assumed to face a choice of *M* mutually exclusive practices for responses to changes in mean temperature and rainfall. In the second stage, MNLESR econometric model was used to investigate the effect of different CSA practices on food security status.

Stage one: Multinomial adoption selection model

At this stage, Multinomial Logit was used to determine the determinants of choice of CSA packages. Farmers were assumed to maximize their food security status, Y_i by comparing the revenue provided by M alternative CSA strategies. The requirement for farmer i to choose any strategy, j over other alternatives M is that $Y_{ij} > Y_{iM}$ $M \neq j$ that is j provides higher expected food security than any other strategy. Y_{ij}^{*} Is a latent variable that represents the expected food security level which contains the observed household and plot characteristics and unobserved features expressed as follows:

$$Y_{ij}^{*} = X_i \beta_j + \varepsilon_{ij} \tag{11}$$

X_i Captures the observed exogenous variables (household and plot characteristics) while the error term ε_{ij} captures unobserved characteristics. The covariate vector X_i is assumed to be uncorrelated with the idiosyncratic unobserved stochastic component ε_{ij}, that is: $E(\varepsilon_{ij} | X_i) = 0$ Under the assumption that ε_{ij} are independent and identically Gumbel distributed that is under the independent irrelevant alternatives (IIA) hypothesis. The selection model (11) leads to a multinomial logit model (McFadden 1973) where the probability of choosing strategy $j\,(p_{ij})$ is:

$$p_{ij} = p(\varepsilon_{ij} < 0 | X_i) = \frac{\exp(X_i \beta_j)}{\sum_{M=1}^{j} \exp(X_i \beta_M)} \tag{12}$$

Stage 2: Multinomial endogenous switching regression model

Here, endogenous switching regression (ESR) was used to investigate the impact of each response practice on food security by applying Bourguignon *et al.* (2007) selection bias correction model. Farm households face a total of M regimes with regime $j=1$ being the reference category (non-responsive). The food security status equation for each possible regime is defined as:

$$\text{Regime}1\; Q_{i1} = z_i\alpha_1 + \mu_{i1} \qquad if \qquad i=1 \tag{13}$$

. .

. .

$$\text{Regime } j\; Q_{ij} = z_i\alpha_j + \mu_{ij} \qquad if \qquad i=j$$

From the above equation, $Q_{ij}'s$ represents the food security status the i th farmer in regime j and the error terms $\mu_{ij}'s$ are distributed with $E(\mu_{ij}|x,z)=0$ and $\text{var}(\mu_{ij}|x,z)=\sigma_j^2$. Q_{ij} Is observed if, and only if, CSA strategy j is used, which occurs when $Y_{ij}^* >_{M\neq 1}^{\max} (Y_{im})$ if the error terms in (12) and (13) are not independent, OLS estimates for equation (13) was biased. A consistent estimation of α_j requires inclusion of the selection correction terms of the alternative choices in equation (12). MESRM assumes the following linearity assumption:

$E(\mu_{ij}|\varepsilon_{i1}......\varepsilon_{ij}) = \sigma_j \sum_{m\neq j}^{j} r_j(\varepsilon_{im} - E(\varepsilon_{im}))$ By construction, the correlation between the error terms in (12) and (13) was zero.

Using the above assumption, equation (12) can be expressed as follows:

$$\text{Regime1: } Q_{i1} = z_i\alpha_1 + \sigma_1\lambda_1 + \omega_{i1} \qquad if \qquad i=1 \tag{14}$$

. .

. .

$$\text{Regime } j: Q_{ij} = z_i\alpha_j + \sigma_j\lambda_j + \omega_{ij} \qquad if \qquad i=j$$

σ_j Is the covariance between $\varepsilon's$ and $\mu's$ while λ_j is the inverse Mills ratio computed from the estimated probabilities in equation (11) as follows:

$$\lambda_j = \sum_{m\neq j}^{j} \rho_j \left[\frac{p_{im} In(p_{im})}{1-p_{im}} + In(p_{ij}) \right]$$

ρ In the above equation represents the correlation coefficient of $\varepsilon's$ and $\mu's$ while ω_{ij} are error terms with an expected value of zero. In the multinomial choice setting expressed earlier, there were $j-1$ selection correction terms, one for each alternative CSA practice.

The standard errors in equation (14) were bootstrapped to account for the heteroskedasticity arising from the generated regressors given by λ_j

Estimation of average treatment effects

At this point a counterfactual analysis was done to examine average treatment effects (ATT) by comparing the expected outcomes of adopters with and without adoption of a particular CSA strategy. ATT in the actual and counterfactual scenarios were determined as follows (Di Falcao & Veronesi, 2011; Teklewold *et al*., 2013):

Food security status with adoption /usage

$$E(Q_{i2}|i=2) = z_i\alpha_2 + \sigma_2\lambda_2 \tag{15a}$$

$$E(Q_{ij}|i=j) = z_i\alpha_j + \sigma_j\lambda_j \tag{15b}$$

Food security status without adoption (counterfactual)

$$E(Q_{i1}|i=2) = z_i\alpha_1 + \sigma_1\lambda_2 \tag{16a}$$

$$E(Q_{i1}|i=j) = z_i\alpha_1 + \sigma_1\lambda_j) \tag{16b}$$

ATT can be defined as the difference between (15a-16a) which is given by:

$$ATT = E(Q_{i2}|i=2) - E(Q_{i1}|i=2) = z_i(\alpha_2\alpha_1) + \lambda_2(\rho_2 - \rho_1) \tag{17}$$

The right hand side indicates the expected change in adopters' mean food security status, if adopters' characteristics had the same return as non-adopters for instance if adopters had the same characteristics as non-adopters while λ_j is the selection term that captured all potential effects of difference in unobserved variables.

Variables used in econometric analysis for both objectives two and three are presented in Table 2

3.6 Measuring food security

To measure food security status of the respondents, Household Food Consumption Score (HFCS) and Household Dietary Diversity Scores were used as proxies for food security of farmers. These tools were developed by WFP and are commonly used as proxies for access to food (WFP, 2009). HFCS is a weighted score based on dietary diversity, food frequency and the nutritional importance of food groups consumed. The FCS of a household is calculated by multiplying the frequency of foods consumed within seven days with the weighting of each food group. The weighting of food groups was determined by WFP according to the nutrition density of the food group. Appendix IV presents the various food components used to determine the HFCS. HDDS is similar to HFCS with slight differences in the components of the various food clusters. While HFCS takes into account food items consumed within 7 days, the HDDS takes into account food items consumed within the last 24 hours. Appendix V shows food group and weights for determination of HDDS.

Table 2: Variables used in econometric analysis

Variable	Description	Measurement	Expected sign
FOODSEC	Food security status of the household	Food consumption score/Household Dietary Diversity Score	
CSA	The number of CSA practices	Discrete	
AGE	Age in years of the household head	Continuous	+/-
GENDER	Gender of the household head	Dummy=1 if male 0=female	
EDUC	Years of education of the household head	Discrete	+/-
H/SIZE	Number of household members in the household	Discrete	+/-
OFF-FARM	Participation in off-farm employment	Dummy=1 if yes 0=otherwise	+/-
ASSETS	Value of productive farm assets	Continuous	+/-
LAND	Owned farm size in acres	Continuous	+
TERRAIN	Terrain of the land	1=sloppy 0=otherwise	+/-
S/FERTILITY	Level of soil fertility	1= poor 2=medium 3=fertile	+/-
EROSION	Severity of soil erosion	1=severe 2=moderate 3=low	+/-
FLOOD	If household experienced floods in the last 5 years	Dummy=1 yes 0=otherwise	+/-
RAINS	If the household experienced insufficient rains in the last 5 years	Dummy=1 yes 0=otherwise	+/-
H/STRMS	if the farm household experienced hailstorms in the last 5 years	Dummy=1 yes 0=otherwise	+/-
DISTNCE	Walking time in minutes to the input and output market	Continuous	+/-
EXTN	Number of annual contacts with extension agents	Discrete	+/-
GRPMSHIP	If the household head is a member of a famer-related group or association	Dummy=1 if a member, 0=otherwise	+
CREDIT	Whether household received credit	Dummy=1 if yes 0=otherwise	+

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter provides the discussion of results for the three specific objectives. Sub-section one presents the results for the first objective whereby individual CSA practices identified in the field were grouped in a Principle Component Analysis to form CSA strategies. In sub-section two, the second objective was addressed whereby factors influencing demand for CSA strategies identified in section were determined in a Poison regression analysis. Finally, in the last sub-section, CSA packages which were identified from the strategies used by farmers were presented. Then factors influencing the choice and the effect of CSA practices on food security status of farmers were determined in a two stage Multinomial Endogenous Switching Regression analysis.

4.1 Identification and grouping of CSA packages used by farmers

As presented in Table 3, there were 14 CSA practices actively in use by small scale farmers. These practices were grouped using a Principal Component Analysis (PCA) whereby related practices based on use were grouped into clusters (components). This was important as it enabled subsequent analysis by fitting the groups into the model and reaching at conclusions. The approach is superior to the use of conventional grouping of practices which would make it difficult to conclude about a group in cases where few practices could represent the entire group.

The components were rotated using orthogonal rotation (varimax method) (Goswami *et al.*, 2014; Chatterje *et al*., 2015) so that smaller number of highly correlated practices would be put under each component for easy interpretation and generalization about a group. The result of the rotation was 4 principal components from a possible 14 extracted with Eigenvalues> 1 following the (Kaiser, 1958) criterion. Principal Component Analysis is useful in reducing the dimensionality of data without loss of much information. Table 3 contains principal components (PCs) and the coefficients of linear combinations called loadings. A popular and intuitive index of goodness of fit in multivariate data analysis is the percentage of explained variance: the higher the percentage of variance a proposed model manages to explain, the more valid the model seems to be. Thus, a visual inspection of Table 3 reveals that the four PCs explained 74.19% of total variability in the dataset. This presents a good fit indicating that the PCA results highly explained the data. A closer look at each column of Table 3 helps to define each component according to the strongly associated practices. The first component explained 35.65 % variance and is correlated with changing crop varieties, use of legumes in crop rotation, use of cover crops, changing planting dates, and efficient use of nitrogen fertilizer all with positive factor loadings. Thus, the component represents crop management practices.

Table 3: Loadings of the four components for CSA compositions

Strategies	**Comp1**	**Comp2**	**Comp3**	**Comp4**	**Communality**
Changing crop varieties	**0.5467**	-0.3965	0.2579	-0.2853	0.6040
Use of legumes in crop rotation	**0.6491**	-0.3903	0.2574	-0.2224	0.6894
Use of cover crops	**0.6257**	-0.3138	-0.2292	-0.1559	0.6344
Changing planting dates	**0.5223**	-0.3779	0.3280	-0.2981	0.6121
Crop and livestock diversification	0.3910	0.3482	**-0.4904**	0.3216	0.6180
Use of organic manure	0.2550	**0.6522**	-0.3156	-0.3036	0.5086
Efficient use of nitrogen fertilizer	**0.5537**	0.2032	0.3940	-0.3311	0.6127
Use of terraces	0.2485	0.3343	-0.3243	**-0.6249**	0.6691
Irrigation	0.3816	0.3986	**0.4546**	0.2423	0.6283
Trees on crop land	0.2459	-0.3013	-0.4518	**0.6024**	0.7183
Food crops on tree land	0.3202	**0.6198**	0.3715	0.3424	0.7419
Use of live barriers	0.3190	-0.3308	-0.3845	**0.5146**	0.6238
Mulching	0.2811	**0.5512**	0.3483	0.3819	0.6500
Use of improved livestock breeds	0.2510	0.3794	**-0.7011**	-0.1492	0.7207
Eigenvalues	4.9160	2.8161	1.5505	1.0287	
Eigenvalues % contribution	35.6543	20.1153	11.0751	7.3479	
Cumulative %	35.6543	55.7696	66.8447	74.1926	

Principal components 2, 3 and 4 accounted for 20.12%, 11.08% and 7.35% variances, respectively. This means that the first four components have more importance in explaining the variance in dataset. The second PC was associated with use of organic manure, planting of food crops on land with trees (as part of agroforestry) and mulching all with positive loadings too. The third PC contained crops and livestock diversification and use of improved livestock breeds both with highly negative loadings and use of irrigation with positive loadings. Finally, the last PC was associated with use of planting trees on crop land and use of live barriers with high positive effects (loadings) and use of terraces with a high negative effect. The communality column shows the total amount of variance of each variable retained in the four components. MacCallum *et al.* (2001) noted that all items in PCs should have communalities of over 0.60 or an average communality of 0.7 for small sample sizes precisely below 50 to justify performing a PCA analysis. With the sample size of 384, the communalities presented in Table 3 meet the minimum criteria as they contribute more than 60% variance in the PCs. For the interpretation of the PCs, variables with high factor loadings and high communalities were considered from the varimax rotation (Lorenzo-Seva, 2013; Goswami *et al.*, 2014).

Table 4 presents the descriptive statistics of composition of each component (climate mart strategies). The most commonly used component was of crop management practices with 96.09% of farmers using at least a unit of this component. This component comprised of practices such as: Use of improved crop varieties, Use of legumes in crop rotation, Use of cover crops, Changing planting dates and Efficient use Nitrogen fertilizers. The second most used component was of general field management practices for soil erosion control used by 81.51% of farmers. This component entailed of use of terraces and contour bunds, planting trees on cropland and use of live barriers.

Table 4: List of climate smart strategies

Group	Percentage of users	Components
Crop management practices (C)	96.09%	Use of improved crop varieties Use of legumes in crop rotation Use of cover crops Changing planting dates Efficient use of Nitrogen fertilizers
General field management practices (F)	81.51%	Use of terraces Planting trees on crop land Use of live barriers
Farm risk reduction practices (R)	39.84%	Diversified crop and animal breeds Irrigation Use of improved livestock breeds
Soil conservation practices (S)	22.92%	Use of organic fertilizers Planting crops on tree land Use of mulching

Farm risk reduction measures were only used by 39.84% of farmers. The practices in this component included: crop and livestock diversification, irrigation and use of improved livestock breeds. Finally, the least used component comprised of specific soil conservation practices which included: use of organic manure, plating crops on tree land, and application of mulching. This component was used by 22.92% of farmers.

4.2 Factors influencing demand for Climate Smart Agricultural practices by small scale farmers

4.2.1 Preliminary diagnostics of the variables to be used in the econometric analysis

This section presents the econometric results of the study. Preliminary diagnostics for statistical problems of multicollinearity and heteroskedasticity were conducted to the variables for socio-economic, institutional and climate related incidences. Multicollinearity, a state of very high inter-correlations or inter-associations among the proposed independent variables was tested using variance inflation factor (VIF) for all continuous variables and results presented in Table 5. The results confirmed that there was no serious linear relationship among the explanatory continuous variables tested since VIF values were less than 10.

For categorical variables, contingent coefficients were calculated and results presented in Table 6. Similarly, results confirmed that there was no serious linear relationship among the categorical explanatory variables because contingent coefficients were less than 0.75 in all cases. By rule of thumb, there was no strong association among all hypothesized explanatory variables. Therefore, all of the proposed potential explanatory variables were used in regression analysis.

Table 5: Variance inflation factor test results for continuous explanatory variables.

Variable	VIF	1/VIF
Land owned with title deed	2.01	0.497034
Years of education of the household head	1.67	0.600461
Annual contacts with extension agents	1.56	0.641958
Log of value of productive assets	1.50	0.667115
Age of the household head	1.42	0.706593
Household size	1.29	0.776057
Distance to the market	1.10	0.905509
Mean VIF	1.45	

Table 6: Contingency coefficient test results for categorical explanatory variables

	Gender	Off_farm	Terrain	Erosion	Fertilityy	floods	hailstorms	Rains	Group	Credit
Gender	1.0000									
Off_farm	0.2335	1.0000								
Terrain	0.0622	0.0036	1.0000							
Erosion	-0.0185	-0.1142	0.0567	1.0000						
Fertility	0.0075	-0.1075	0.0292	0.1078	1.0000					
floods	-0.0148	-0.0099	0.0474	-0.1305	0.0012	1.0000				
hailstorms	-0.0251	-0.0203	-0.0591	-0.0790	-0.0601	0.0428	1.0000			
Rains	0.0529	0.0263	-0.0497	-0.0224	0.0627	-0.0569	0.0386	1.0000		
Group	0.1667	0.2448	-0.0324	-0.0201	-0.0093	0.0313	-0.1138	-0.0036	1.0000	
Credit	0.2648	0.3039	-0.0006	-0.0009	0.0284	0.0360	-0.0651	-0.1031	0.5593	1.0000

To detect heteroskedasticity for all hypothesized explanatory variables, white test was used and results presented in Table 7. Unlike the Breusch-Pagan test which would only detect linear forms of heteroskedasticity, white test was preferably applied as it incorporates both the magnitude as well as the direction of the change for non-linear forms of heteroskedasticity (Williams, 2015).

Table 7: Test for heteroskedasticity

Source	***chi*^{2}**	**df**	**P**
Heteroskedasticity	224.85	162	0.0008
Skewness	35.78	17	0.0049
Kurtosis	4.92	1	0.0266
Total	265.54	180	0.0000
chi^2(162) =224.85			
Prob > chi2 =0.0008			

White's general test is a special case of the Breusch-Pagan test, where the assumption of normally distributed errors has been relaxed. The results indicated presence of heteroskedasticity as a *chi*^{2} of 224.85 was significantly large. To counter this problem, robust standard errors were reported in the subsequent analyses.

4.2.2 Factors influencing demand for CSA practices

Demand for CSA strategies presented in Figure 4 was measured by the number of individual CSA components (strategies) generated in PCA. The range of number of components was between 0 and 4 for non-adopters and full adopters respectively. The mean number of CSA strategies used was 2 with about 44.8% of farmers implementing packages having two sets of strategies. The results reveal that 3.6% of farmers did not use any strategy (non-users) while another 8.3% of farmers used only 1 set of strategies. Further, 12% of farmers used a package with all the four sets of strategies while 31.3% of farmers used packages with 3 sets of strategies.

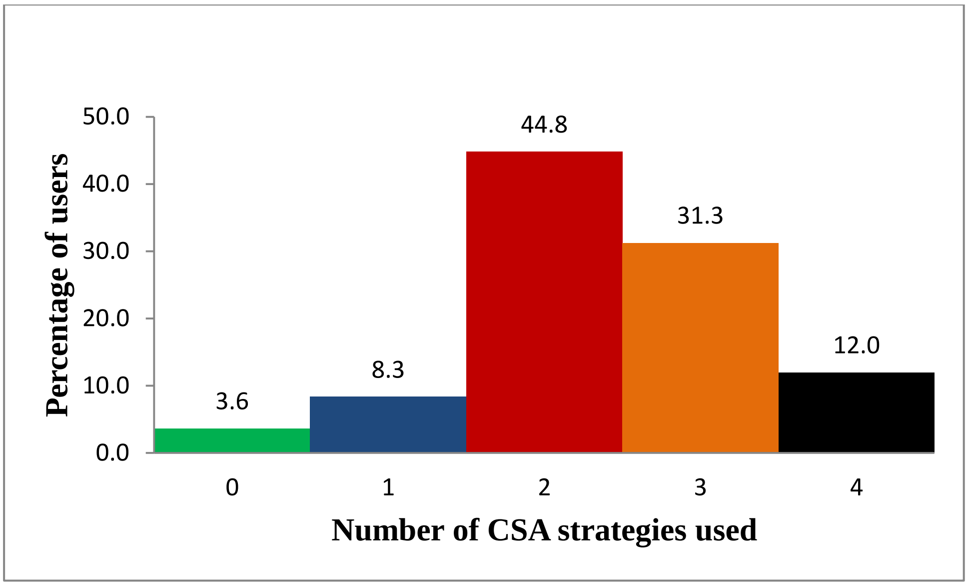

Figure 4: Farmers level of usage of CSA strategies

Factors influencing the demand for CSA practices were determined in a poison regression analysis. The results for Poisson regression model are presented in Table 8. A goodness of fit chi-square estimated but after the regression analysis and was not statistically significant indicating that the data fitted the model well. Further a confirmation with Negative Binomial Regression presented in Appendix II produced the likelihood ratio test for alpha = 0 not significant indicating that Poisson model was appropriate. A significant alpha=0 could be an indication of a potential over-dispersion problem in which case Negative Binomial Regression would be appropriate.

The results in Table 8 suggest that many factors influence the demand for CSA practices. They include: age and gender of the household head, household size, farm size, Log of value of productive farm assets, participation in off-farm employment, membership to a farmer group, access to credit and annual contacts with extension service agents significantly influence farmers’ decision to implement CSA practices.

Age of the household head was negatively associated with higher demand for CSA practices at 10% level of significance. This implies that older farmers were less likely to implement many strategies compared to younger ones. Factors associated with old age such as a shorter term planning horizon, and loss of energy, as well as being more risk averse could be leading to the negative effect of age on demand for CSAs.

Table 8: Standard Poisson model results on factors influencing farmers' demand for CSA practices

Variable	Coefficients	Robust standard errors	P>Z
Socio-economic factors			
Age	-0.0014*	0.0008	0.0920
Gender	0.1538***	0.0294	0.0000
Years of education of household head	-0.0032	0.0027	0.2380
Household size	0.0155***	0.0046	0.0010
Participation in off-farm employment	0.0478**	0.0197	0.0150
Log of value of farm productive assets	0.0467***	0.0088	0.0000
Farm size	0.0770***	0.0100	0.0000
Perceptions on farm characteristics			
Perception on terrain	-0.0145	0.0167	0.3870
Perception on severity of soil erosion	0.0059	0.0119	0.6220
Perception on soil fertility	-0.0065	0.0151	0.6680
Climate related shocks			
Floods	0.0016	0.0179	0.9290
Hailstorms	-0.0057	0.0167	0.7340
Rains	0.0144	0.0178	0.4160
Institutional characteristics			
Distance to the market	0.0001	0.0002	0.5850
Group membership	0.0916***	0.0257	0.0000***
Annual contacts with extension agents	0.0159***	0.0034	0.0000***
Credit access	0.1749***	0.0252	0.0000***
Constant	0.8556***	0.1052	0.0000***
Pearson goodness-of-fit = 93.27472			
Prob > chi2(357) = 1.0000			

Notes: ***, **,* indicates significant at 1%, 5% and 10% levels respectively. Since the goodness of fit chi-square is not statistically significant indicates that Poisson Regression Model is a better model

This observation is similar to that of Bernier *et al*. (2015) who noted that age was negatively correlated with adoption of climate change adaptation strategies. The explanation was that older farmers were more risk averse and mostly less educated. Contrary, Challa & Tilahun (2014) noted that age of farmers positively influenced the probability of adoption of climate change related technologies because it is related to farming experience which improves skills for better farming.

Gender of the household head was positive and significant at 1 percent showing that it is associated with higher demand (usage) for CSA strategies. The results revealed that male headed households had higher likelihood of higher demand for CSA practices than female headed. This may be explained by the dominant culture that males still have exclusive rights to make farm decisions regarding both short term and long term adjustments. Further, security of land tenure for women is not guaranteed which could deny them access to important facilities like credit. Gbegeh & Akubuilo (2012) found similar results and reported that in many parts of Africa, women are often deprived of property rights due to social barriers. Consequently, they have fewer capabilities and resources than men in so far as land management is concerned. Ndamani & Watanabe (2016) also reported that women are less able to diversify income sources and adapt to climate change because of other domestic responsibilities and less control of financial resources.

Household size was positive and significant at 1 percent. Larger households were associated with higher demand for CSA practices. This is plausible because majority of farmers in the County use family labor. Thus, larger household size guaranteed labor availability, particularly for labor intensive CSA practices. Nkonya *et al*. (2008) explained that the bulk of labor for most farm operations in sub-Saharan Africa is provided by family members rather than hired persons. Therefore, lack of adequate family labor accompanied by inability to hire labor constrains adoption of crucial farming technologies. Teklewold *et al*. (2016) observed that larger household size was associated with use of important CSA practices like modern crops seeds combined with water management and efficient use of inorganic fertilizers.

Participation in off-farm employment was positively associated with higher demand for CSA practices and significant at 5 percent. This implies that farmers who were engaged in off-farm activities were more likely to use many CSAs. Off-farm income improves farm liquidity as it provides an alternative source of financing agricultural activities. The income could be used to purchase farm inputs and meet labor costs involved. Previous study by Muzari *et al*. (2012), postulated that off-farm income facilitates adoption of high yielding and resilient adaptation practices. They argued that off-farm income could finance production to meet labor bottlenecks, resulting from higher labor requirements that new technologies demand. Contrary, Mathenge *et al.* (2014) argued that engaging in off-farm activities divert time and effort away from agricultural activities. This reduces investment in farm technologies and eventual availability of labor.

Farm assets had a positive and significant influence on use of CSA practices at 1% significance level. The results suggested that farmers with higher value of productive farm assets had a higher likelihood of having high demand for CSAs. Availability of assets like farm animals and tools provide a means of diversifying farming hence reducing the potential risk of total failure making farmers less risk averse in adopting CSA strategies. These findings are similar to Johnson *et al*. (2016) who emphasized that relatively low value of agricultural assets limits technology adoption. Farmers with low value of agricultural assets require technologies with little requirements for such possessions (Johnson *et al*., 2016). Similarly, Obayelu *et al*. (2014) argued that ownership of productive assets represents their wealth which reflects their past achievement and ability to bear risks of trying CSA technologies. This then motivates them to experiment them.

The demand for CSA practices was further influenced by size of farm owned by farmers. This was significant at 1 percent. Farmers who owned larger pieces of land had higher likelihood of demand for CSA practices. Land is a primary fixed input in agricultural production and having a larger piece provides an opportunity for farmers to experiment many different CSAs. A previous study by Deininger *et al*. (2008) reported that land size was strongly correlated with increased likelihood to invest in soil and water conservation activities, and that it more than doubles the predicted number of hours spent on each activity. Similarly, Menale (2010) reported that farm size had a positive association with adoption of many CSA strategies because it represents wealth or financial capital, which relaxes liquidity constraints in implementing the practices.

Group membership was significant at 1 percent and associated with higher probability of demand for CSA practices. Membership provides a link to access such facilities as credit and extension which are vital ingredients to adoption of CSA technologies. This is because through group interactions, members get to exchange ideas, handle farm demonstrations and also get connections to dissemination of important research findings. This is consistent with Gido *et al*. (2015) who noted that membership in farmer related groups and organizations increases the ease with which extension agents reach members, reduces the cost of service delivery through economies of scale and guarantees a higher number of contacts between members and service providers. Further, groups could also provide security in microfinance institution for members hence enabling them to implement the ideas they get from extension service providers. Earlier research findings in Nepal and Bangladesh also showed that farmers belonging to cooperative organizations have higher likelihood of using climate change adaptation practices. The reason was that group members could share ideas, discuss problems and take collaborative decisions (Tiwari *et al*., 2014; Uddin *et al*., 2014).

Annual contacts with extension service providers was significant at 1% and positively associated with higher demand for CSA practices. Extension agents play an important role in creating awareness and demonstration of new CSA technologies. Essentially, the more the contacts the more the knowledge acquired because sustainable farming requires a whole set of new skills, including observation, monitoring and risk assessment. Demand driven extension in the County is offered by PALWECO, One Acre Fund and other NGOs. These agencies have climate change mitigation measures attached to their services delivered. They inform farmers about the changing climatic conditions which enhances the chances of the farmers to adapt to climate change. Thus, exposure to such information increased the farmer's awareness and adaptation thereafter **(**PALWECO, 2012**).** Gido *et al*. (2015) found that extension services play a central role of providing support for institutional mechanisms designed to support the dissemination and diffusion of knowledge among farmers and demonstration of gains from new technologies. Akudugu *et al*. (2012) also argues that extension helps farmers understand the importance of modern technology and enhance the accuracy of implementation of the technology packages.

Finally, access to credit positively influenced the probability of higher demand for CSA practices and significant at 1 percent. An increase in amount of credit received significantly led to more CSA practices used. Credit increases financial resources of farmers, reduces cash constraints and allows farmers to purchase important inputs. Presumably, with access to capital, farmers tend to use capital-intensive CSAs as well as pay costs for labor intensive technologies. Adekemi *et al*. (2016) argued that credit increases the farmers' economy to purchase improved seed, fertilizer and other CSA inputs. However, this is only as far as the profitability of the technology supersedes other investment alternatives available to the farmer. Beshir *et al.* (2012) highlighted that if households get sufficient credit, they are able to purchase climate smart improved seeds and fertilizers on time.

4.3 Determinants of choice of specific CSA packages and its effect on household food security

The results in this section are presented in two stages. First, the determinants of choice of different combinations of CSA strategies that form CSA packages are given followed by their impact on food security. The reason is that CSA practices can be adopted in a wide range of different combinations and these matter very much in terms of impact on household's food security (Branca *et al*., 2011). Given the set of available packages, understanding what drives an individual to select specific packages is important for policy direction.

The results presented in Table 9 indicate that seven (shown in bold) out of 16 possible combinations/packages were used by farmers. Few farmers (3.6%) were non-users/non-adopters of any CSA package. About 2.6% of farmers used package $C_1F_0R_1S_0$. This package comprised of crop management practices and farm risk reduction measures only. Another 4.4% used package $C_1F_0R_1S_1$ that had crop management, farm risk reduction measures and soil management practices. Further, 7.0% of farmers used package $C_1F_1R_0S_1$ that contained crop management, field management and soil conservation practices. Another 8.3% of farmers used package $C_1F_0R_0S_0$ that contained only crop management practices. Approximately, 12% of farmers used package $C_1F_1R_1S_1$ with all the four groups of CSA strategies. About 21% used package $C_1F_1R_1S_0$ that contained crop management, general field management for soil erosion control and farm risk reduction practices only). The largest share of farmers (41.1%) used a package $C_1F_1R_0S_0$ that had (crop management and general field management for soil erosion control). This indicates the efforts of many subsistence farmers to achieve food production despite the challenges of land degradation caused by soil erosion. This observation is similar to the findings of FARA (2015) which suggested that farmers in the region executed such responsive strategies for survival amidst challenges of climate change A keen look at Table 9 reveals that all users of CSA practices (96.4% of all farmers) used packages that included at least a crop management practice. This observation demonstrates the need of most farmers to meet their basic crop production for food generation.

Table 9: Specification of CSA strategy combinations to form the packages

Choice(j)	Binary quadruplicate	C=crop management		F=field management		R=risk reduction		S=specific soil management		Frequency	percentage
		C_0	C_1	F_0	F_1	R_0	R_1	S_0	S_1		
1	$C_0F_0R_0S_0$	✓		✓		✓		✓		14.0	3.60
2	$C_0F_0R_0S_1$	✓		✓		✓			✓	0.00	0.00
3	$C_0F_0R_1S_1$	✓		✓			✓		✓	0.00	0.00
4	$C_0F_1R_1S_1$	✓			✓		✓		✓	0.00	0.00
5	$\mathbf{C_1F_1R_1S_1}$		✓		✓		✓		✓	**45.0**	**11.7**
6	$\mathbf{C_1F_1R_1S_0}$		✓		✓		✓	✓		**82.0**	**21.1**
7	$\mathbf{C_1F_1R_0S_0}$		✓		✓	✓		✓		**157**	**41.1**
8	$\mathbf{C_1F_0R_0S_0}$		✓	✓		✓		✓		**32.0**	**8.30**
9	$C_0F_1R_0S_1$	✓			✓	✓			✓	0.00	0.00
10	$\mathbf{C_1F_0R_1S_0}$		✓	✓			✓	✓		**10.0**	**2.60**
11	$C_1F_0R_0S_1$		✓	✓		✓			✓	0.00	0.00
12	$C_0F_1R_0S_0$	✓			✓	✓		✓		0.00	0.00
13	$C_0F_1R_1S_0$	✓			✓		✓	✓		0.00	0.00
14	$C_0F_0R_1S_0$	✓		✓			✓	✓		0.00	0.00
15	$\mathbf{C_1F_0R_1S_1}$		✓	✓			✓		✓	**17.0**	**4.40**
16	$\mathbf{C_1F_1R_0S_1}$		✓		✓	✓			✓	**27.0**	**7.00**
Total										384	100

Note: The binary quadruplicate represents the possible CSA packages. Each element in the quadruplicate is a binary variable for a CSA combination: Crop management (C), General field management for soil erosion control Farm risk reduction (R) and Soil management practices (S). Subscript 1 = adoption and 0 = otherwise.

4.3.1 Determinants of choice of specific CSA packages

This section describes the factors that influence the choice of CSA packages, and then followed by quantification of the effect of using packages on food security status of farmers in the last stage. This was achieved using the multinomial endogenous switching regression (MNLESR) model which is a two stage regression analysis model. The first stage of the MNLESR is the Multinomial logit model which determines factors that influence the choice of CSA packages. This is an important stage as it guides on the necessary interventions to improve the adoption of CSA packages. The second stage presented in section 4.3.2 determined the effect of usage of CSA packages on household food security. The marginal effects from the MNL model measured the expected change in the probability of a particular choice being made with respect to a unit change in an independent variable were reported in Table 10.

Non-use of all practices ($C_0F_0R_0S_0$) was the base category compared to other seven packages (refer to Table 9 for the packages) used by farmers. The results show seven sets of parameter estimates, one for each mutually exclusive combination of strategies. The Wald test that all regression coefficients are jointly equal to zero is rejected [$\chi 2$ (119) = 445.52; p = 0.000]. Thus, the results show that the estimated coefficients differ substantially across the alternative packages.

Age of the household head was negatively associated with usage of $C_1F_0R_0S_0$ and positively associated with usage of $C_1F_1R_0S_1$ at 10% and 5% significant levels respectively. Increase in age of the household head by one year reduced the likelihood of using package $C_1F_0R_0S_0$ by 0.19% while increased the likelihood of using $C_1F_1R_0S_1$ by 0.16%. This indicates that as age increases, farmers shift from smaller packages to larger ones. Older farmers may be more experienced with regard to production technologies and may have accumulated more physical and social capital thus to afford larger and better packages. Contrary, Shongwe *et al*. (2014) noted that old age had a negative relationship to adopting climate change adaptation strategies explaining that agriculture is a labor intensive venture which requires healthy, risk bearing and energetic individuals.

With regard to gender of the household head, male headed households were 2.7% more likely to use package $C_1F_1R_1S_0$ that contains crop management practices, field management, farm risk reduction practices only at 5% significant level relative to $C_0F_0R_0S_0$ (non-use of any CSA practices). Women generally face constraints in terms accessing resources and time. This may explain the negative relationship with usage of CSA practices in this study. Barnard *et al*. (2015) reported that gender remains a significant barrier to the adoption of CSAs by women; stemming largely from customary gender roles. They further stated in the report that women have less access than men to resources such as land, inputs, credit, education, and extension services, all of which may be important to support transitions to CSA. Land ownership systems also present more entrenched barriers to female-led households. Land tenure systems in Western Kenya, for example, require women who want to adopt CSA to obtain permission from male relatives thus derailing them (Silici, 2010).

Years of education of the household head was negatively correlated with usage of $C_1F_1R_0S_0$. One more year of education reduced the probability of using this package by 2% at 5% significant level. It could be that educated farmers opted out of this package to other lucrative ventures since education could guarantee them. This is contrary to Gido *et al*. (2015) who argued that higher levels of education tend to build the innovativeness of farmers as well as improve on their information processing, which are important in the adoption of improved agricultural practices.

The results presented in Table 10 also revealed a positive and significant relationship between productive farm assets (a proxy of wealth and usage of CSAs). Resource endowed farmers (those with greater value of productive farm assets) were more likely to use larger packages $C_1F_1R_1S_0$ and $C_1F_1R_1S_1$ as opposed to non-use of any package. Precisely, the probability of using these packages increased by 0.14% and 0.07% respectively for resource endowed farmers. This is likely because wealthier farmers have both the capacity to acquire CSA technologies, particularly capital intensive like u as e of improved livestock breeds and crop varieties. Further these assets help farmers to absorb the risks associated with failure and the time it takes before realizing meaningful effects of using CSA. This is consistent with Teklewold *et al*. (2016) who noted that lack of productive assets limits the ability to adopt climate smart practices that require huge resource allocation. However, on the other hand the probability of using $C_1F_1R_0S_0$ reduced by 7.2% with increase in farm assets.

Table 10: Parameter and marginal effects estimates for the determinants CSA combination of strategies by MNL

Variables	**$C_1F_0R_0S_0$**		**$C_1F_0R_1S_0$**		**$C_1F_0R_1S_1$**	
	Coefficient(RSE)	**dy/dx**	**Coefficient(RSE)**	**dy/dx**	**Coefficient(RSE)**	**dy/dx**
Socio-economic factors						
Age	-0.08(0.04)	-0.0019*	-0.02(0.04)	0.0007	-0.02(0.04)	0.0015
Gender	-1.70(1.17)	-0.0434	-0.84(1.48)	0.0045	-0.15(1.36)	0.0340
Years of education of household head	0.01(0.10)	0.0013	0.06(0.16)	0.0015	0.05(0.12)	0.0033
Household size	0.30(0.42)	0.0075	0.15(0.45)	-0.0006	0.13(0.42)	-0.0020
Participation in off-farm employment	-0.06(1.06)	-0.0251	0.49(1.54)	0.0022	1.07(1.14)	0.0341
Log of value of farm assets	0.49(0.37)	0.0032	0.47(0.49)	0.0009	0.34(0.41)	-0.0045
Farm size	-0.20(0.61)	-0.0378***	0.37(0.70)	-0.0104	0.28(0.61)	-0.0268**
Perceptions on farm characteristics						
Perception on terrain of land	0.13(0.91)	-0.0007	0.41(1.13)	0.0057	-0.12(1.02)	-0.0123
Perception Severity of soil erosion	-0.20(0.66)	-0.0107	-1.60(0.73)	-0.0342**	0.40(0.78)	0.0198
Perception of soil fertility	-1.36(0.85)	-0.0064	-1.26(0.92)	-0.0002	-1.03(0.84)	0.0105
Bad incidences						
Frequent floods	0.92(0.89)	0.0284	-0.91(1.17)	-0.0266	-0.01(1.05)	-0.0204
Hailstorms	0.76(0.92)	0.0268	0.52(1.22)	0.0052*	0.16(0.97)	-0.0053
Insufficient rains	-1.47(1.07)	-0.0023	-1.39(1.26)	0.0008	-1.05(1.29)	-0.0169
Institutional factors						
Walking time from farm to market	0.01(0.02)	0.0002	-0.01(0.02)	-0.0003	-0.02(0.02)	-0.0005*
Membership to a farmer group	1.63(1.64)	0.0279	1.88(1.95)	0.0148	0.82(1.69)	-0.0126
Contacts with extension agents	0.19(0.17)	-0.0046	0.36(0.23)	0.0021	0.42(0.20)	0.0073
Access to credit	-1.05(1.57)	-0.0461*	-0.51(1.81)	-0.0044	-0.48(1.65)	-0.0083
Constant	1.60(4.32)		-0.18(5.62)		-4.10(4.64)	

Note: $C_0F_0R_0S_0$ is the reference base category in the MNL; ***: significant at 1% level; **: significant at 5% level; *: significant at 10% level

Table 10 Cont.: Parameter and marginal effects estimates for the determinants CSA combination of strategies by MNL continuation

Variable	$C_1F_1R_0S_0$		$C_1F_1R_0S_1$		$C_1F_1R_1S_0$	
	Coefficient(RSE)	dy/dx	**Coefficient(RSE)**	dy/dx	**Coefficient(RSE)**	dy/dx
Socio-economic factors						
Age	-0.06(0.03)	-0.0028	0.01(0.04)	0.0016**	-0.05(0.03)	0.0016
Gender	-1.11(1.11)	-0.0284	-1.25(1.25)	-0.0047	-1.01(1.21)	-0.0047
Years of education of household head	-0.05(0.08)	-0.0204**	0.06(0.12)	0.0019	0.05(0.10)	0.0019
Household size	0.14(0.41)	-0.0239	0.40(0.42)	0.0056	0.25(0.42)	0.0056
Participation in off-farm employment	0.31(0.95)	-0.0518	-0.33(1.18)	-0.0168	0.71(1.04)	-0.0168
Log of value of farm assets	0.32(0.35)	-0.0722***	0.49(0.40)	0.0014	0.84(0.39)	0.0014***
Farm size	0.82(0.57)	-0.0171	0.40(0.63)	0.0110*	1.45(0.60)	0.0110***
Perceptions on farm characteristics						
Perception on terrain of land	0.29(0.84)	0.0995	-0.57(1.00)	-0.0177	-0.28(0.92)	-0.0177
Perception Severity of soil erosion	-0.08(0.65)	-0.0452	-1.88(0.82)	-0.0451**	0.64(0.70)	-0.0451***
Perception of soil fertility	0.97(0.78)	0.1871***	-1.78(0.95)	-0.0128	-2.29(0.83)	-0.0128***
Bad incidences						
Frequent floods	0.48(0.83)	0.0205	1.59(0.98)	0.0330*	0.25(0.96)	0.0330
Hailstorms	0.25(0.79)	-0.0126	1.13(0.97)	0.0193	0.09(0.90)	0.0193
Insufficient rains	-1.34(0.99)	0.0628	-2.44(1.10)	-0.0311	-1.70(1.07)	-0.0311
Institutional factors						
Walking time from farm to market	0.01(0.02)	0.0011	-0.02(0.02)	-0.0007**	-0.01(0.02)	-0.0007**
Membership to a farmer group	1.39(1.57)	0.1888**	2.17((1.80)	0.0221	0.04(1.68)	0.0221**
Contacts with extension agents	0.23(0.17)	-0.0296***	0.46(0.20)	0.0046	0.39(0.18)	0.0046**
Access to credit	-0.54(1.52)	-0.1571**	-0.17(1.69)	0.0028	1.07(1.67)	0.0028***
Constant	2.94(3.91)		-1.90(4.57)		-6.94(4.43)	

Note: $C_0F_0R_0S_0$ is the reference base category in the MNL; ***: significant at 1% level; **: significant at 5% level; *: significant at 10% level

Table 10 Cont.: Parameter and marginal effects estimates for the determinants CSA combination of strategies by MNL continuation

Variable	$C_1F_1R_1S_1$	
	Coefficient(RSE)	dy/dx
Socio-economic factors		
Age	-0.04(0.04)	0.0000
Gender	13.13(1.29)	0.0271**
Years of education of household head	0.00(0.11)	0.0000
Household size	0.48(0.43)	0.0004
Participation in off-farm employment	1.37(1.11)	0.0012
Log of value of farm assets	1.04(0.42)	0.0307*
Farm size	1.97(0.65)	0.0013**
Perceptions on farm characteristics		
Perception on terrain of land	-0.76(0.96)	0.0011
Perception Severity of soil erosion	0.60(0.72)	0.0007
Perception of soil fertility	-1.87(0.86)	0.0007
Bad incidences		
Frequent floods	0.67(1.01)	0.0003
Hailstorms	-0.22(0.97)	0.0006
Insufficient rains	-1.73(1.11)	0.0004
Institutional factors		
Walking time from farm to market	0.01(0.02)	0.0001
Membership to a farmer group	1.07(1.78)	0.0000
Contacts with extension agents	0.47(0.20)	0.0002
Access to credit	-0.19(1.72)	0.0001
Constant	-28.57(4.93)	

Note: $C_0F_0R_0S_0$ is the reference base category in the MNL; ***: significant at 1% level; **: significant at 5% level; *: significant at 10% level

Farm size owned was also correlated with usage of CSA practices. It was revealed that it was positively associated with use of packages $C_1F_1R_0S_1$, $C_1F_1R_1S_0$ and $C_1F_1R_1S_1$ and negatively associated with use of package $C_1F_0R_0S_0$ and $C_1F_0R_1S_1$. This implies that an increase in size of land by 1 acre (0.40ha) increased the probability of using packages, $C_1F_1R_0S_1$, $C_1F_1R_1S_0$ and $C_1F_1R_1S_1$ by, 1.1%, 1.1% and 0.13% respectively while reduced the probability of using packages $C_1F_0R_0S_0$ by 3.8% and $C_1F_0R_1S_1$ by 2.7%. It follows therefore that farmers with larger farm size had the capacity to use larger packages as opposed to non-usage of any package. Availability of land with permanent ownership provides opportunity to experiment these important technologies thus influencing usage of the large packages. This result is consistent with the result of Akudugu *et al*. (2012), Idrisa *et al*. (2012) and Salam *et al*. (2011) who obtained positive and significant result on farm size. Users of package $C_1F_0R_0S_0$ were less likely to use the package with increase of their farm sizes. This is fascinating since the reverse would be expected. The possible explanation could be that these farmers chose to rent out their increasing farms for other users rather than farming. Renting in farmers may not be motivated to implement long term packages thus reducing the usage of CSA practices on these particular farms.

The perception of severity of soil erosion by farmers was negatively associated with use of the following packages: $C_1F_0R_1S_0$, $C_1F_1R_0S_1$ and $C_1F_1R_1S_0$. The probability of using these packages reduced by 3.4%, 4.5% and 4.5% respectively for the farmers who regarded their plots as severely eroded. It appears that farmers were highly motivated to implement CSA practices on less severely eroded farms and vice versa. In essence these farmers were not quite responsive to countering the effects of severe soil erosion but were rather discouraged by severe soil erosion in implementing CSA technologies. Contrary, Haghjou *et al*. (2014) noted a positive correlation with adoption of many soil conservation practices with the argument that farmers were responsive to soil degradation brought by soil erosion.

The perception of farmers towards soil fertility of the farm had a positive and significant influence on the usage of $C_1F_1R_0S_0$ and a negative influence on the usage of $C_1F_1R_1S_0$. The likelihood of using packages $C_1F_1R_0S_0$ and $C_1F_1R_1S_0$ increased by 18.7% and reduced by 1.3% respectively for the farmers who regarded their farms as being more fertile. This implies that farmers who regarded their farms as being more fertile were more likely to use package $C_1F_1R_0S_0$ as opposed to non-use of any package. But those who regarded their farms as being less fertile implemented a larger package $C_1F_1R_1S_0$ that basically contain more soil nutrient enriching practices. Manda *et al*. (2015) argues that the propensity to adopt sustainable agricultural practises such as improved maize is expected to be greater on plots with fertile soils, because most improved maize varieties require the application of expensive inorganic fertilisers.

Factors related to past experiences with extreme weather conditions by farmers were also correlated with the usage of CSA packages. For instance farmers who experienced frequent floods caused by heavy downpours in the past were more likely to use package $C_1F_1R_0S_1$.The probability of using this package increased by 3.3% for the farmers who experienced frequent floods in the recent past. It is likely that these farmers were keener to the menace thus implementing a responsive strategy to curb it. Contrary, Menale *et al*. (2010) noted that adoption of improved climate change adaptation technologies such as crop rotation and drought resistant seeds are negatively and significantly influenced by harsh conditions brought by flooding such as waterlogging and frost stress.

Past experience with hailstorms was also positively associated with the use of package $C_1F_0R_1S_0$. It was revealed that, the likelihood of using this package increased by 0.52% for farmers who had experienced frequent hailstorms in the recent past. Similarly, these farmers could be implementing a responsive strategy that included farm risk reduction through diversified production means. Previous study by Gebeyehu (2016) had a contrary result where frequent hailstorms were the main sources of production risks related to climate change that farmers discouraged adoption of production techniques for yield stability in rural Amhara Ethiopia.

Distance (measured by walking time) to the input and output market negatively influenced usage of CSA practices. Precisely, an increase in time taken to reach the market by 1 minute reduced the probability of using packages $C_1FR_1S_1$, $C_1F_1R_0S_1$ and $C_1F_1R_1S_0$ by 0.05%, 0.07% and 0.07% respectively. The distance to input and output markets reflects the transaction costs associated with buying inputs and taking produce to the market. Menale *et al*. (2013) noted that apart from affecting the access to the market, distance can also affect the accessibility of new technologies, information and credit institutions thus having a negative relationship.

Group membership had a positive and significant influence on the usage of packages: $C_1F_1R_0S_0$ and $C_1F_1R_1S_0$. Rather than not using any package, belonging to a farmer group increased the probability of using these two packages by 18.8% and 2.2% respectively. Farmer groups are important channels through which extension agents and other farmer service providers (like insurance) use to access farmers. Secondly, farmers lobby for external support services like loans that could facilitate acquisition and implementation of these important CSA technologies in group guarantees. This is similar to the findings of Komba & Muchapondwa (2015) and Varma (2016) who reported that farmer groups play an important role in credit access, information sharing, technology demonstration and final use.

The number of contacts with extension service providers was positively correlated with use of $C_1F_1R_1S_0$ and negatively correlated with use of $C_1F_1R_0S_0$. One more annual contact with extension agents increased the probability of using $C_1F_1R_1S_0$ by 0.46% but reduced the probability of using $C_1F_1R_0S_0$ by 3.0%. This suggests that extension service played a crucial role in implementation of a larger package by farmers. It further suggests that the information disseminated had inclusion of a climate change dimension that promoted the use of this package. However on the other hand, reduction in probability of using $C_1F_1R_0S_0$ suggests that the goal of promoting CSA technologies by extension service agents had mixed effects. It appears that some farmers did not trust the efficiency of the information thus opting not to use any package and perhaps depend on traditional modes of production. This is consistent with the findings of a study in Zambia by Arslan *et al*. (2014) which indicated that extension agents were involved in a lot of activities that include delivering inputs and administering credit, hence farmers may question their skills impacting on their trust and eventual decline in implementation.

Finally, access to credit had a positive and significant influence on use of $C_1F_1R_1S_0$ but a negative influence in use of $C_1F_0R_0S_0$ and $C_1F_1R_0S_0$. The results indicate that farmers who received credit in the previous farming season were 0.28% more likely to use $C_1F_1R_1S_0$. Credit access is crucial as it enable farmers to meet costs involved in implementing CSA technologies. Similarly, Shiferaw *et al*. (2015) explain that credit constraints negatively influence investment in improved seed and inorganic fertilizers, suggesting that liquidity-constrained households (those who need credit, but are unable to find it) are less likely to adopt CSA technologies that require cash outlays. Access to credit reduced the probability of using packages $C_1F_0R_0S_0$ and $C_1F_1R_0S_0$ by 4.6% and 15.7% respectively. A negative influence of credit access to usage of $C_1F_0R_0S_0$ and $C_1F_1R_0S_0$ may suggest that these farmers diverted credit to fund non-farming expenses like school fees and medical thus opting not use any package.

4.3.2 Average adoption treatment effects for the CSA packages

After determining the drivers of choice of CSA packages in the first stage, treatment effects were determined in the second stage to find the effect of usage of the packages on household food security. The ordinary least squares regression of Household Food Consumption Scores (HFCS) and Household Diversity Scores (HDDS) of the households were estimated for each combination of CSA practices, taking care of the selection bias correction terms from the first stage. At this stage, treatment effects which are the most important part of this stage were reported.

Appendices III and IV presents the food categories for HFCS and HDDS. For interpretation, Household Food Consumption Scores (HFCS) were preferred to Household Dietary Diversity Scores as the latter only captures meals taken within 24 hours which may not include occasional meals taken on particular days like market days within a week. It is also important to note that the two scores were strongly correlated (0.97) as indicated in Table 11.

Table 11: Pairwise correlation between HDDS AND HFCS

	HDDS	**FCS**
HDDS	**1.0000**	
FCS	**0.9652*** **	**1.0000**

Table 12 presents the average adoption effects of food consumption scores (HFCS) and HDDS under actual and counterfactual conditions. In Table 12, X_1 represents the treated group (adopters) and X_2 represents untreated (non-adopters), β_1 represents treated characteristics (adoption state) and β_2 untreated characteristic (non-adoption state). The level effect is the difference in food security status as a result of usage of the specified package. Hence, the level effect for the treated characteristic is $\beta_1(X_1 - X_2)$, while that of untreated characteristic is $\beta_2(X_1 - X_2)$. The treatment/returns effect is the difference in coefficients as a result of adoption of the specified package. Therefore, the treatment/returns effect for the treated is $X_1(\beta_1 - \beta_2)$, while that of untreated is $X_2(\beta_1 - \beta_2)$. The impact is as a result of the difference between treated with treatment characteristics and the untreated with untreated characteristics $(\beta_1 X_1) - (\beta_2 X_2)$.

Table 12: Impact of use and non-use of CSA packages on food security estimated using HFCS of farmers by ESR

Package		HFCS			HDDS		
		Treated characteristics(β_1)	Untreated characteristics(β_2)	**Impact/ returns**	Treated characteristics(β_1)	Untreated characteristics(β_2)	**Impact/ returns**
$C_1F_0R_0S_0$	Treated (X_1)	49.14(1.92)	49.52(0.96)	-0.38	5.31(0.21)	6.06(0.12)	-0.25
	Untreated(X_2)	52.35(2.23)	65.07(0.80)	-12.72	5.68(0.019)	6.89(0.07)	-1.21
	Level effects	-3.21	-15.54***	-15.93	-0.37*	-0.83***	-1.58
$C_1F_0R_1S_0$	Treated	65.75(7.24)	56.52(2.25)	9.23	7.20(0.55)	6.36(0.18)	0.84
	Untreated	63.29(3.68)	63.65(0.78)	-0.36	6.69(0.31)	6.74(0.07)	-0.05
	Level effects	2.46	-7.13***	2.1	0.51	-0.38**	0.46
$C_1F_0R_1S_1$	Treated	61.09(3.37)	80.84(2.72)	-19.75	6.56(0.30)	6.63(0.10)	0.07
	Untreated	57.40(2.63)	63.82(0.80)	-6.42	6.25(0.23)	6.76(0.06)	-0.51
	Level effects	3.69	17.02***	-2.73	0.32	-0.13	-0.20
$C_1F_1R_0S_0$	Treated	55.77(1.09)	65.81(1.01)	-10.04	6.14(0.09)	7.04(0.09)	-0.90
	Untreated	59.44(0.96)	69.11(0.93)	-9.67	6.29(0.09)	7.18(0.09)	-0.89
	Level effects	-3.67***	-3.30***	-13.34	-0.15	-0.14	-1.04
$C_1F_1R_0S_1$	Treated	63.89(2.18)	69.99(0.80)	-6.10	6.70(0.23)	7.52(0.09)	-0.82
	Untreated	63.59(1.94)	63.69(0.83)	-0.10	6.76(0.07)	6.75(0.14)	0.01
	Level effects	0.30	6.30***	0.20	-0.05	0.76***	-0.05
$C_1F_1R_1S_0$	Treated	74.70(1.03)	62.72(0.83)	11.98	7.66(0.10)	6.35(0.09)	1.31
	Untreated	75.75(1.20)	60.64(0.89)	15.11	7.90(0.11)	6.51(0.08)	1.39
	Level effects	-1.05	2.08*	27.09	-0.25**	-0.16*	1.15
$C_1F_1R_1S_1$	Treated	83.92(1.01)	68.04(0.82)	15.88	8.48(0.11)	7.06(0.10)	1.42
	Untreated	79.09(1.23)	53.51(0.82)	15.58	8.19(0.12)	6.76(0.07)	1.43
	Level effects	4.83***	4.53***	30.41	0.29**	0.31***	1.72

Note: Standard errors are in parenthesis. C=crop management, F=field management, R=risk reduction, S= specific soil management.

The results in Table 12 reveal that except users of $C_1F_0R_1S_0$, $C_1F_1R_1S_0$ and $C_1F_1R_1S_1$, all the rest using other packages would be better off in the counterfactual scenarios (non-usage) suggesting availability of other better options. All packages that included farm risk reduction practices apart from $C_1F_0R_1S_1$ had a positive impact on the welfare of farmers. This implies that farmers need to manage their farm risks to be assured of improved food security in the uncertain events of climate change.

For larger packages ($C_1F_1R_0S_1$, $C_1F_1R_1S_0$ and $C_1F_1R_1S_1$), all users were more food secure compared to their counterparts who did not use CSAs in the actual scenarios. Based on these results a complete package with crop management practices, field management practices and farm risk reduction practices and soil management ($C_1F_1R_1S_1$) had the greatest overall effect on the welfare of farmers estimated using both HFC and HDDS. Thus farmers may be more food secure if they use climate smart technologies within this package.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Three conclusions emerge from the analyses of the three objectives:

1. The results indicate that adoption rate of CSAs was still low with crop management practices being the most dominant perhaps to meet food production for subsistence. The findings indicate that specific soil management and improved livestock management practices were less adopted.

2. The results further indicated that likelihood of higher demand for CSA strategies was positively influenced by gender of the household head, household size, participation in off-farm employment, farm size, and membership to a group, number of annual contacts with extension service agents, and credit access and age of the household head. This observation provides a wider spectrum of interventions to improve the demand for CSAs.

3. The key finding is that CSAs have the potential to alleviate food insecurity among small scale farmers if used in combinations and to a larger extend. Thus in conclusion, improved adoption of these practices could help reduce food insecurity for small scale farmers.

5.2 Recommendations

To improve the demand for CSA practices, farmers should be motivated to join and participate in farmer organizations so that they could share farming information. Further, farmers could also stand a chance to be linked conveniently with extension service providers and farm financing agents. Crucially, off-farm income improves farm liquidity which provides an alternative means of financing farm operations. Thus, the County and national government together with development partners should invest in important infrastructure like electricity and roads which could spur rural based economic activities making it easier for farmers to engage in off-farm income generating activities.

Finally, farmers should be encouraged to incorporate all CSAs as much as possible to have a higher effect on food security status. Also, farmers should be sensitized on the need to invest in productive farm assets to enable them absorb risks associated with climate change at the same time enhancing their ability to uptake important CSAs. The sensitization could be done in groups by extension service providers. Land fragmentation should also be discouraged through civic education and engagement in alternative income generating activities for farmers to benefit more from CSAs when practiced on relatively bigger portions of land.

5.3 Areas of further research

Further research should be done on analysis of potential to adopt selected capital intensive CSA practices like soil testing, soil nutrient micro dosing (precision agriculture), and intensive livestock production systems including livestock insurance which could inform on necessary interventions to promote the usage of these CSA practices.

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APPENDIX I: QUESTIONNAIRE

EFFECT OF CLIMATE SMART AGRICULTURAL PRACTICES ON FOOD SECURITY OF SMALL SCALE FARMERS IN TESO NORTH SUB-COUNTY, KENYA

Questionnaire No……………………………

You are one among several farmers in this area who have been selected for this study. The study seeks to evaluate the uptake of Climate Smart Agricultural practices and its effect on household food security status. The information you will give will be strictly confidential.

Date…………………………... (EN) Enumerator's name……………………….......

A1) SOCIO-ECONOMIC CHARACTERISTICS OF THE RESPONDENT

GEOGRAPHICAL LOCATION

1) Ward………………………………………………
2) Sub-location……………………………………
3) Village…………………………………………….

A2) PROFILE OF THE HOUSEHOLD HEAD

i) What's the gender of the household head? 1=Male 0=Female…[ ]
ii) What's the age of the household head……………………………………years.
iii) Indicate years of education of household head……………………………years.
iv) Indicate years of education of the spouse…………………………………years.
v) Indicate the household size (number of members)……………………………….
vi) Does the household head participate in off-farm employment? 1=Yes 0=No[ ]
vii) If yes, what is the average monthly income from off-farm employment?.........Kshs

v) Indicate which of the following assets are owned							
Asset	**Number**	**Unit cost**	**Total value**	**Asset**	**Number**	**Unit cost**	**Total value**
Livestock and types				**Farm equipment**			
Zebu cattle				Water tank			
Improved cattle				Wheelbarrow			
Local goats				Tractor			
Improved goats				Ox plough			
Sheep				*Pangas*			
Local poultry				*Jembe*			
Improved poultry							

Rabbits							
Local pigs							
Improved pigs							
Improved poultry							
Rabbits							

B) FARM CHARACTERISTICS

i) Do you own land? 1=Yes 2=No...[   ]
ii) What is the size of land owned with a title deed?...acres
iii) What is the size of land in acres rented out?..acres
iv) What is the size of land in acres rented in?..acres
v) What is the size of land under cultivation?..acres
vi) What is the terrain of your farm? 1= Sloppy 0= Otherwise………………………...[   ]
vii) What is the severity of the soil erosion? 1=very severe 2=moderate 3=Not severe.[   ]
viii) Farmers own perception of the soil fertility 1=very fertile 0=moderate 3=poor….[   ]
ix) What is the farming experience of the household head in years?.............................years
x) What is the average walking time to the input/output market?.................................minutes.
xi) What is the average walking time from the homestead to the farm?........................minutes.

C) FOOD SECURITY STATUS

(C1) How many days in the last seven days did your household eat any of the food categories in the list below? (Tick appropriately the type of food eaten on each particular day) leave blank on each day a particular food was not eaten.

S/N	Food item	7days ago	6 days ago	5 days ago	4 days ago	3 days ago	2 days ago	yester day
1	Rice							
2	Wheat meal							
3	Ugali (Maize meal)							
4	Porridge							
5	Millet meal							
6	Sorghum meal							
7	Beans							
8	Groundnuts							
9	Other pulses							
10	Fresh milk							
11	Sour milk							
12	Yoghurt							

13	Tea with milk							
14	Beef							
15	Pork							
16	Poultry meat							
17	Eggs							
18	Fish							
19	Omena							
20	Sukuma wiki							
21	Cabbage							
22	Indigenous vegetables							
23	Sugar/honey							
24	Mangoes							
25	Oranges							
26	Bananas							
27	Other fruits							
28	Oils/cooking fat							
29	Sweet potato							
30	Irish potato							
31	Cassava							
32	Other tubers							
33	Other foods(specify)							

C2) In your own opinion, would you say that the food taken in your household is enough for every member? 1=Yes 0=No…………………………………………………………[ ]

D) CLIMATE CHANGE RELATED INFORMATION

D1) Would you say that there have been severe changes in climate in the last 20 years? 1=Yes 0=No……………..[ ]

D2) What bad incidences related to climate have you experienced in this area over the last 20 years? 1= Droughts 2 =Hail storms 3=floods 4= Others (specify)……………………[ ]

D3) Have you made any changes in your farming practices following the bad incidences? 1=Yes 0= No…………………………………………………………………………….[ ]

D4) If yes, which of the following practices have you adopted? (put a circle on adopted practices) **1=Use of improved crop varieties 2=Use of legumes in crop rotations 3= Use of cover crops 4=Changing planting dates 5=Diversification of livestock breeds and crop varieties 6=Organic fertilization (use of compost, animal and green manure 7=Efficient use of nitrogen fertilizer 8= Use of terraces, contour farming 9=Tied ridge system 10=Irrigation 11=Reduced/ minimum/zero tillage 12=Trees on cropland 13=Crop on tree land 14=Use of live barriers 15=Mulching 16=Use of improved livestock breeds**

17=Others
(specify)…………………………………………………………………………………………
…D5 Would you say that the above adopted strategies have helped you to cope with climate change? 1=Yes 0=No ………………………………………………………………..[ ]

D6) What are the challenges involved in adoption of the above strategies? 1 =Lack of capital 2 = Lack of information 3=Shortage of labor 4=Lack of access to water 5=others (specify)…………………………… …………………………………….......................[ ]
D7) Which among the following are your sources of information on climate change? [ ]
1=Radio 2=Government extension service officers 3=NGO 4=Relatives 5=TV 6=Other farmers
D8) Is the household head a member of any formal group? 1= Yes 0=No [ ]
D9) If yes, what benefits does he/she derive from membership in the groups?...[ ]
1=Information on credit 2=General advice on farming 3=Information on climate change 4=Help in credit access 5=Others (specify)
…………………………………………………………………………………………
D10) Did you receive any extension services related to climate change last year? 1=Yes 0=No…………………...[ ]
D11) If yes, how many times were you visited by extension officers? (Indicate number of times)………………...times
D12) Do you have access to credit? 1=Yes 0=No………………………………………………………………………………...[ ]
D13) If yes, indicate the amount received last year…………………………………………………………..….Kshs
D14) Is the credit used in investing on on-farm adjustments to climate change? 1=Yes 0=No……………………………………………………………………………….[ ]

APPENDIX II: NEGATIVE BINOMIAL MODEL RESULTS ON FACTORS INFLUENCING FARMERS' DEMAND FOR CSA PRACTICES

Variable	**Coefficients**	**Robust standard errors**	**P>Z**
Socio-economic factors			
Age	-0.0014*	0.0008	0.0920
Gender	0.1538***	0.0294	0.0000
Years of education of household head	-0.0032	0.0027	0.2380
Household size	0.0155***	0.0046	0.0010
Participation in off-farm employment	0.0478**	0.0197	0.0150
Log of value of farm productive assets	0.0467***	0.0088	0.0000
Farm size	0.0770***	0.0100	0.0000
Perceptions on farm characteristics			
Perception on terrain	-0.0145	0.0167	0.3870
Perception on severity of soil erosion	0.0059	0.0119	0.6220
Perception on soil fertility	-0.0065	0.0151	0.6680
Climate related shocks			
Floods	0.0016	0.0179	0.9290
Hailstorms	-0.0057	0.0167	0.7340
Rains	0.0144	0.0178	0.4160
Institutional characteristics			
Distance to the market	0.0001	0.0002	0.5850
Group membership	0.0916***	0.0257	0.0000
Annual contacts with extension agents	0.0159***	0.0034	0.0000
Credit access	0.1749***	0.0252	0.0000
Constant	0.8556***	0.1052	0.0000
/lnalpha	-44.51125		
alpha	4.67e-20		
Likelihood-ratio test of alpha=0: chibar2(01) = 0.00 Prob>=chibar2 = 1.000			

Notes: ***, **,* indicates significant at 1%, 5% and 10% levels respectively. The likelihood ratio test for alpha = 0 not significant indicating that the NBR model is same as standard Poisson model

APPENDIX III: FOOD GROUPS FOR HFCS BY WFP

Food Item	Food Group	Weight
Rice Wheat/other cereals Potato (including sweet potatoes)	Cereals and tubers	2
Pulses/beans/nuts	Pulses	3
Milk/Milk products	Milk	4
Meat and fish Poultry Eggs Fish and sea food(fresh/dried)	Meat and fish	4
Dark green vegetables-leafy Other vegetables		1
Sugar/honey		0.5
Fruits		1
Oil		0.5
Spices, tea, coffee, salt, fish power, small amounts of milk for tea	Condiments	0

The maximum FCS has a value of 112 which would be achieved if a household ate each food group every day during the last 7 days. The total scores are then compared to pre-established thresholds. Poor food consumption: 0 to 2, borderline food consumption: 28.5 to 42 and acceptable food consumption: > 42

APPENDIX IV FOOD GROUPS FOR HDDS

Food groups	Score
Cereals	1
White tubers and roots	1
Vegetables	1
Fruits	1
Meat	1
Eggs	1
Fish and other sea food	1
Legumes, nuts and seeds	1
Milk and Milk products	1
Oils and fats	1
Sweets	1
Spices, condiments and beverages	1

Dietary diversity scores are calculated by summing the number of food groups consumed in the household or by the individual respondent over the 24-hour recall period out of a maximum of 12 per day.