CLIMATE CHANGE PERCEPTIONS AND ADAPTIVE WATER MANAGEMENT STRATEGIES AMONG FARMERS IN KAKAMEGA COUNTY, KENYA

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DECLARATION AND APPROVAL

Declaration

I, Ibrahim Ochenje Mumani, declare that this thesis is my original work and has not been presented for a degree award in any other university.

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DEDICATION

I dedicate this thesis to Mr and Mrs Mumani. I would like to express my gratitude for sacrifices they have made towards this journey. To my supervisors for their invaluable support and advice.

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ABSTRACT

A number of climate variables such as solar radiation temperature, cloud cover, precipitation, wind speed, and humidity, affect water resources due to climate change. This has led to changes in soil moisture, reduced stream runoff, reduced ground water recharge and increased transpiration that has led to water stress which ultimately leads to decreased crop yields. Deteriorating water resources at farm level caused by Climate change has led farmers to undertake adaptive water management strategies to respond to the adverse effects of climate change. This study assesses climate change perceptions by farmers and adaptive water management strategies undertaken at farm-level in Kakamega County, Kenya. Ordered probit and multivariate probit (MVP) were used to analyze data collected from 159 households in Kakamega County. Ordered probit was used to analyse the levels of farmers' perception to climate change based on water resources while descriptive statistics were used to characterise adaptive water management strategies undertaken by farmers in Kakamega County. Multivariate probit was used to analyze factors affecting adaptive water management strategies among farmers. Ordered probit results indicated that gender, farm size, distance to the main source of water, contact with an extension officer, access to climate change information via radio and wealth status significantly explained the level of farmers' perception of climate change based on water resources. Major adaptive water management practices identified in the area of study were: use of cropping strategy, irrigation and water harvesting, soil and water conservation practices as well as protection of water catchment. Study findings from MVP model showed that age, farmer experience ,farm size, distance to a water source, produce market distance, distance to tarmac road, membership to a group, access to extension services, access to climate information through agricultural extension officers and climate change perceptions on amount of rainfall received influenced adaptive water management strategies. These findings can therefore inform the national and county

government as wells as non-government organizations on major policy interventions that are likely to support farmers to undertake adaptive water management practices. Examples of such policy measures include better access to climate change and agricultural information, market and wealth that will lead to resilience of water resources to climate change. Better access to climate change and agricultural information can be facilitated by provision of free extension services to the farmers whereas, improvement of rural infrastructure such as roads will enhance access to both input and output markets. Increased access to resources can be achieved by provision of affordable agricultural credits to farmers through establishment of effective pro-poor microfinance institutions.

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LIST OF ABBREVIATIONS AND ACRONYMS

CAADP	Comprehensive Africa Agriculture Development Programme
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GoK	Government of Kenya
IISD	International Institute for Sustainable Development
IPCC	Inter-governmental Panel on Climate Change
IWH	Irrigation and Water harvesting
IWMI	International Water Management Institute
KNBS	Kenya National Bureau of Statistics
MDGs	Millennium Development Goals
MVP	Multivariate probit
NCCRS	National Climate Change Response Strategy
NCCAP	National Climate Change Action Plan
NGOs	Non-governmental organizations
RUM	Random Utility Model
SDGs	Sustainable Development Goals
SWC	Soil and Water conservation
UNDP	United Nations Development Programme

CHAPTER 1 : INTRODUCTION

1.1 Background Information

Agriculture as the main source of rural livelihood and food security in less developed countries faces a number of constraints such as declining soil fertility and subdivisions of land into small units which are uneconomical due to increased population density. In recent years, climate change has been a challenge facing agriculture. Human activities have contributed significant amount of Greenhouse gasses (GHGs) to the atmosphere. According to the Third Assessment Report on climate change, the concentration of GHGs in the atmosphere have grown by 31 percent for carbon dioxide, 151 percent for methane and 17 percent for nitrous oxide (IPCC, 2001). Increase in GHGs in the atmosphere has led to global warming and has had an impact on the world's climate known as climate change. Inter-governmental Panel on Climate Change (IPCC, 2007) defines climate change as significant alteration in mean temperature over long periods of time, typically decades or longer caused by natural variability or anthropogenic causes. However, United Nations Framework Convention on Climate Change (UNFCCC) describes climate change as alterations that interfere with the global atmospheric composition, attributed only to human activities as opposed to climate variability which is attributed only to natural causes. Climate change is projected to have a range of impacts that adversely affect agriculture and water resources with regard to reduced water availability and more frequent extreme weather conditions (IPCC, 2007).

Climate change as a major global challenge has greatly affected countries that depend on agriculture as the main contributor to economic growth, especially in sub Saharan Africa (Dixon *et al*. 2001). World Bank (2009) reports that without innovative interventions, climate change will eventually cause a decline in annual Gross Domestic Product (GDP) by 4 percent in Africa. Climate change has also been an impediment to the attainment of the Millennium Development Goals (MDGs), particularly to eliminate poverty and hunger (MDG1) as well as to promote environmental sustainability (MDG7). Furthermore, effects of climate change threaten achievement of food security and economic growth in Sub-Saharan Africa (Ngigi, 2009; Parry *et al*., 2005). Climate change has a potential of negatively affect economic growth. The incremental impacts of climate change over the years have capability to reverse much progress made towards the achievement of the MDGs and Vision 2030 (GoK, 2012a). For instance, rain-fed agriculture continues the principal source of staple food and a livelihood source to the bulk of the population in Kenya and makes them vulnerable to climate change. Climate change also has adverse effects on natural resources, and environment (UNDP, 2007).

Water as a natural resource faces constraints from rapid increase in population, pollution and destruction of water catchment areas. These constraints are compounded by climate change effects mainly through increase in temperature which causes water loss by evaporation as well as causing increased frequency of drought and flood occurrences (IPCC, 2001). These effects are likely to have significant implications on water resources at farm level thus affecting agricultural productivity. The United Nations Environmental Programme-UNEP (1996) report indicates that reduced water availability due to climate change will pose a major challenge to agriculture, especially in developing countries. It was projected that water demand will rise by between 12-27 percent to match the growing demand of food by 2025 (IWMI, 2000). Thus, adaptive water management strategies which will guarantee availability of water is key for crop production. Adaptive water management strategies refer to interventions aimed at improving water availability and utilization for agricultural production to reduce the risk facing farmers by the changing climate. This would ensure both the current and future needs are met as well help in achieving economic growth in sub Saharan Africa (Ngigi, 2009).

Majority of people in sub Saharan Africa largely derive their livelihoods from climate sensitive natural resources and agriculture. As such, lack of better management of natural resources increases the vulnerability of the majority of people to extreme climatic occurrences, such as droughts and floods (UNEP, 2000). According to IPCC (2007, p. 976), climate change vulnerability is “the degree to which a system is susceptible to, or unable to cope with adverse effects of climate change, including climate variability and extremes”. Vulnerability of farmers to climate change depends on the ability of their ability to adapt to climate change, extent of exposure and sensitivity of the people affected (IPCC, 2007).

Practical solutions to climate change constraints are mainly mitigation and adaptation. Mitigation measures are activities that limit the magnitude of climate change (Broadmeadow & Ray, 2005). Adaptation strategies, on the other hand are appropriate actions taken to prevent or minimize adverse effects of climate change or taking advantage of opportunities that may arise. National Climate Change Action Plan (NCCAP) also defines climate change adaptation as “measures undertaken to reduce vulnerability, to avoid or minimize the impacts of climate change, and enable people to respond to climate risks by moving towards a climate-resilient society”.

Adaptive water management strategy is one of the main adaptation measures that can be practised by farmers. Such water management strategies include water storage, harvesting of rainwater, sustainable groundwater use, soil and water conservation, conservation agriculture (CA), and increased water use efficiency (Ngigi, 2009).

Government of Kenya (GoK) through NCCAP has prioritized water resource management to respond to impact of climate change on water resources (GoK, 2012a), there is a need to have a better understanding in perception and adaptive climate change strategies based on water resources at farm-level. This is likely to enhance formulation of policies for successful management of water resources for agricultural production (Kamau, 2010). Kakamega County is one of the leading counties with regard to food production in Kenya (Nyoro *et al*., 2004). The county is already experiencing adverse effects of climate change that threatens water resource for agricultural production (GoK, 2012a). Due to climate change, the area is characterised by erratic rainfall, unusual heavy rains are followed by weeks of dry period, and increased incidences of prolonged drought. In light of these uncertainties, there is a looming risk to food security, water security and sustainable livelihoods among crop farmers in Kakamega County.

1.2 Statement of the Research Problem

According to IPCC (2007) report, 75 to 250 million people world-wide will be affected by water scarcity aggravated by climate change by the year 2020. Furthermore, rain fed agriculture and food access in several African countries is expected to decline by 50 percent leading to poverty, food insecurity and loss of livelihoods (IPCC, 2007). It is also projected that climate change will increase frequency and intensity of extreme weather events like droughts and floods, which will lead to loss of productive assets, personal possessions and even life (IPCC, 2001).

Effects of climate change have been observed in Kenya, and are projected to intensify in the future if there is no worldwide effort to combat global warming. For instance, famine cycles in Kenya have been reducing significantly from 20 years in 1964-1984, to 12 years in 1984-1996, two years in 2004-2006 and yearly in 2007, 2008 and 2009 due to increased frequency of droughts (GoK, 2010 a). The impact of the 2008-2011 drought are estimated to have cost 968.6 billion shillings and triggered an economic slowdown in Kenya's economy by about 2.8 percent annually during that period. Livestock and agriculture sub sectors were most affected by the 2008 drought, with decline in productivity by about 72 percent (GoK, 2012a). Issues of climate change agriculture is critical given that agriculture is one of the six sectors that were identified to have the potential of contributing 10 percent growth in the GDP as envisioned by the Kenya Vision 2030.

Climate change has compounded the problems of water scarcity where majority of SSA countries are classified as economically water scarce. In Kenya the annual renewable freshwater supply of has declined from 647 cm^3 per capita to 493cm^3 per capita (World Bank, 2011). This is significantly below the 1,000 m^3 per capita requirement and underscores the need to invest more in water resource management technologies in order to tap water resources potential, particularly for agriculture where there is a looming threat of climate change. (IISD[1], 2008). The government of Kenya over time has come up with various strategies and policies such as Water Act 2002, Forest Policy 2007, and NCCRS 2010 to address the impact of climate change in agricultural production. Despite the various policies, very little has been done to understand about climate change effects on farm-level water resources thus, farmers in areas such as Kakamega County are vulnerable to climate change impacts on farm-level water resources.

An extensive adaptive water management is required to lessen vulnerability of farmers to future climate change effects on water resource at farm-level. Stakeholders should also invest more on water resource management technologies and water infrastructure to increase

[1] International Institute for Sustainable Development (IISD).

climate change resilience. Although some studies have been carried out on adaptation to climate change in developing countries (Nhemachena & Hassan, 2007; Deressa, 2007; Kitinya *et al*., 2012), these studies do not particularly put emphasis on climate change perception and its linkage to adaptive water management strategies adopted by farmers. In Kenya, many studies have also concentrated in ASAL areas where the effects of droughts can be easily manifested, even though farmers in areas in non ASAL areas such as the study area continue to suffer the effects of climate change.

The evidence that climate has changed and has continued to change underscores the need to assess farmers' perception and adaptation to climate change. Farmers' knowledge about climate change is key and largely determines what strategies they adopt in their attempt to reduce its effects. The knowledge on farmers' perception to climate change is necessary in formulation of policy guides on adaptation strategies given that farmers' subjective judgement of climate change impacts on water resources may influence their response to unfavourable impacts of climate change. Whereas the knowledge farmers' perception is key, climate change perceptions and its linkages to adaptive water management strategies in Kakamega County of western Kenya is still unknown. There is also lack of empirical information on various adaptive water management strategies that are undertaken by farmers to reduce vulnerability in areas such as the study area. Assessing different levels of farmers' perception and factors influencing adaptive water management strategies is therefore necessary for successful efforts to combat negative effects of climate change on water resources at farm level. The study sought to assess the perception of climate change with regard to water resources.

1.3 Purpose of the Study

The purpose of the study was to assess climate change perceptions by smallholder farmers and adaptive water management strategies undertaken at farm level in Kakamega County Kenya.

1.3.1 Specific Objectives

The specific objectives of the study were to:

- Determine socioeconomic factors influencing farmers' perception of climate change effects on water resources at farm-level in Kakamega County.
- Characterize adaptive water management strategies adopted by farmers in the face of climate change in Kakamega County.
- Examine factors influencing the choice of adaptive water management strategies in Kakamega County.

1.3.2 Research Question

i. Which are the adaptive water management strategies that are used by farmers in Kakamega County?

1.3.3 Hypotheses

The study hypothesized that:-

1. Socio economic factors do not influence farmers' perception of climate change effect on farm-level water resources.
2. Socio economic factors do not influence adaptive water management choices undertaken by farmers.

1.4 Justification of the Study

Kakamega County is a major food production areas in the country (Nyoro *et al*., 2004). Generally, farmers in Kakamega County are vulnerable to climate change because they majorly depend on rain-fed agriculture for livelihood. Moreover, most of them lack adequate capital to invest in innovative adaptation strategies and infrastructure to respond to increased climate variability (GoK, 2012 a). To enhance agricultural production and water resource use, there is need for farmers to adapt to climate change and reduce their vulnerability. Therefore, policies that could address constraints that climate change pose on water resource at farm level would be significant in agricultural production.

The study's findings is likely to contribute towards realization of SDG-2, that is, to end hunger, achieve food security and improved nutrition and promote sustainable agriculture by 2030 , SDG- 6 that seeks to ensure availability and sustainable management of water and sanitation for all as well as SDG -13 which seeks to urgently combat climate change and it is impacts. Furthermore, it corresponds to CAADP pillar 1 on land and water management sustainability. As envisioned, the study's findings inform policies that promote agricultural water management for smallholder farmers as a climate change adaptation practice.

CHAPTER 2 : LITERATURE REVIEW

This chapter presents review of literature in relation to the effects of climate change on water resources and the adaptive water management strategies at farm level among farmers. Climate change and subsequently its effects on water resources are presented. It covers literature on climate change in Africa; linkages between climate change, water resource and agriculture; water management as an adaptive strategy to climate change and climate change perceptions.

2.1 Climate Change in Africa

A more understanding of global climate change has been realised by more rigorous evaluation and analysis of data from many studies carried out in different parts of the world. (Meehl *et al*., 2007; Boko *et al*., 2007; Hulme *et al*., 2001; Desanker & Magadza, 2001) There is evidence that climate is changing (IPCC, 2013). These evidence include increase in, melting of snow and ice caps, global average temperature, increases in ocean temperatures and ocean acidity, and rising sea level. The general consensus by scientists is that changes in climate are largely caused by human activities (IPCC, 2013).

In Africa, average temperature is higher than it was 100 years ago and the model-based predictions of future climate change for Africa clearly indicate that temperature rise will continue and may accelerate (Hulme *et al*., 2001). There was a temperature rise in Africa at a rate of about 0.05°C per decade in the 20th century (IPCC, 2001). The temperature increase has changed the intensity and frequency of extreme events which includes floods, droughts and heavy precipitation (Christensen *et al*., 2007). Kenya has recorded an average temperature rise of about 1°C for the last 50 years and it is projected to accelerate to about 3°C by 2050 (GoK, 2010 a; IPCC, 2007). According to Kenya meteorological department

(2008), the recent prolonged and severe droughts in Kenya are widely perceived to be indicators of the changing climate. Moreover, the drought cycle in most parts of country seems to be narrowing (GoK, 2010 a). Evidence of frequent flood and destructive, reduced or delayed rainfall is increasingly experienced in most parts of Kenya (GoK, 2010 a). Increased prevalence of certain pests and diseases, and changing crop production conditions are also other indicators of climate change. As stated by the stakeholders in their contributions at the National Climate Change Response Strategy (NCCRS) workshops, key sectors and land use systems in Kenya are already affected by the impact of climate change. (GoK, 2012 b). These sectors include: agriculture; livestock particularly in Kenya’s rangelands; wildlife and tourism sectors; forestry; water resources; aquatic and marine resources; health and physical infrastructure.

2.2 Linkages between Climate Change, Water Resource and Agriculture

There is are linkages between climate change, agriculture and water resources. Kenya is categorized into six agro-climatic zones by moisture index designated as zones I, II, III, IV, V and VI (Sombroek *et al*., 1982). These zones range from areas with a high potential for cropping, to arid regions. Additionally, Kenya has generally experienced increasing temperatures and rainfall changes as provided by the Kenya Meteorological Department over the last fifty years. (GoK, 2010a). Agriculture accounts for approximately 70 percent of global water use (Ngigi, 2009). In addition, agriculture contributes about 13.5 percent of annual greenhouse gas emissions and is partly considered as climate change problem (Nelson *et al*., 2009). Agriculture is, however, part of the solution too, it contributes in climate change mitigation process, mainly through biomass production, carbon sequestration and better land use management.

Changes in temperatures and precipitation patterns, increased incidences droughts and floods directly affect agricultural production (Ngigi, 2009). Impact of climate change such as droughts, floods and increase in evaporation rates due to temperature rise, directly affect surface water resources. It also affects the recharge rates of ground water resources that vary in proportion to the changes in precipitation (Green *et al*., 2007). Consequently, agriculture production is affected by the changes in availability of water resources, hence water resources, agriculture and climate change are inseparably linked.

According to IWMI strategic plan 2009-2013, rain-fed farming systems in sub-Saharan Africa is experiencing low productivity, leading to food insecurity and increased poverty rates particularly in rural areas. This is partly because of inadequate or non-existent water management strategies. Adaptive Management of water which involves better management of rainwater and soil moisture, as well as investment in small irrigation technologies and supplementary irrigation can improve agricultural productivity and reduce poverty. O'Brien *et al* (2008) reported that majority of the population largely depend on natural resources that are sensitive to climatic conditions, and have inadequate capacity to adapt. Water is a natural resource that is critical for livelihoods in Africa. Majority of the population, especially the poor, rely on rain fed agriculture that is sensitive to climate variation (Hassan & Nhemachena, 2008). Changes in rainfall amount and pattern caused by climate change, affect local water systems. These in turn may alter the distribution of seasons which temperature and rainfall conditions allow agricultural production (Fischer *et al.*, 2002).

Adaptation to impacts of climate change in farming systems is needed to develop resilience to high intensity rainfall and extended drought periods. Studies such as De Wit & Stankiewicz, 2006; IISD, 2007 have shown that existing agricultural and water systems have been affected due to climate change and have negative consequences on livelihoods. More efforts are therefore required, for management of land and water resources so as to achieve food security and improve living standards in rural areas (ICID, 2001).

2.3 Climate Change Adaptation and Adaptive Water Management

As global population rises, demand for water also keeps on increasing making water resource an important subject in international agenda since 1992, emphasizing the impact of climate change on water resources (Love, 1999). In Kenya, the renewable freshwater availability per capita has been declining over time and it is projected to fall to $235m^3$ by 2020 (GoK, 2010 a). These water shortages have been aggravated over the years by climate change, increased population pressure on water resources, overexploitation of wetlands and water catchment degradation. Climate change also causes unusually high rainfall intensity or flooding. Both water shortages and unusual heavy rains affect agricultural production. Climate change impact studies in African agriculture show that adaptation can significantly reduce vulnerability (Kurukulasuriya & Mendelsohn, 2006a; Seo & Mendelsohn, 2006; Mano & Nhemachena, 2006). According to Ngigi (2009), agricultural water management is among practices for agriculture to withstand stresses caused by climate variability and change.

There are several adaptation strategies in the water sector. They can be categorised as either supply-side or demand-side (Boko *et al.*, 2007; Bates *et al.*, 2008). Supply-side options mainly involve increasing storage capacity or improved access to water resources while demand-side options include; adjusting to irrigation techniques; adoption of water-efficient technologies; rain water harvesting and soil moisture conservation techniques that enhance moisture retention. Demand-side options also involve management of water to prevent water logging, erosion and leaching during intensive rainfall (Adejuwon, 2008). The Kenya government through the Agricultural Sector Development Strategy included climate change adaptation as a priority (GoK, 2010 a). National Climate Change Response Strategy (NCCRS) provided more details on the prioritized activities in agriculture. With regard to adaptation strategies, the NCCRS prioritized investing in; water harvesting, soil and water conservation, weather information systems, as well as research on drought tolerant crop varieties (GoK, 2010 a).

Use of soil and water conservation techniques is an important adaptive water management. Soil and water conservation techniques include a range of practices such as cover cropping, minimum tillage, mulching, terracing, soil bunds ridges, bench terraces and grass strips. Nyangena (2007) argued that understanding social factors that influence adoption of soil and water conservation technology among farmers in Kenya can increase the pace of development. Deressa *et al*. (2009) argued that farmers will use soil and water conservation (SWC) to preserve moisture to cope with increased temperature especially in drier regions.

Climate Change Convention held in Nairobi-Kenya in 2006 recognized rain water harvesting as an alternative option that can address current water demand and also provide water security against future droughts especially in African countries (Mashood *et al*., 2011). Bouwer (2000) also points out that water storage is needed to protect water resources against changes in climatic conditions. This includes, storing water during times of water surplus and use it during water shortage. Promotion of agriculture that enhance efficient use of water resources through drip irrigation, water recycling and reuse, mulching and appropriate land-use techniques is also important in ensuring availability of water for agricultural production. Some studies have assessed factors influencing farmers' adaptation to climate change. For example, Maddison (2006) reported that choice of adaptation strategies by farmers were influenced by different socio-economic factors. These factors include education of the household head, market access, farmers' experience, access to information through extension services. Similar findings were reported by Hassan & Nhemachena, (2008). Therefore assessing the factors that influence adaptation to climate can provide useful guide to successful adaptation by farmers. This study however focused on adaptive water management at the farm level to address climate change effects on-farm water resources.

2.5 Climate Change Perception by Farmers

In Sub Saharan Africa, a number of studies such as Deressa *et al*., 2009; Gbetibouo, 2009; Benedicta *et al*., 2010 have been carried out on perceptions and adaptation to climate change. Most farmers have indicated that there has been increase in temperature and a decrease in the amount of rainfall over the years. Other studies have gone further and assessed the accuracy of farmers' perception to climate change. For instance, Gbetibouo (2009) compared farmers' perception of long-term changes in temperature and precipitation with climate trends recorded at the nearby meteorological stations. The study found out that the farmers' perceptions were in line with the actual climate data.

Studies have reported that most farmers, who perceive that climate is changing, adapt to respond to the adverse effects caused by climate change (Ishaya & Abaje, 2008; Thomas *et al*., 2007; Mertz *et al*., 2009). A number of studies have been carried out to assess determinants of climate change perceptions. For instance, Akter & Bennett (2009), showed that perception of climate change is influenced by socio-economic and environmental factors such as farming experience, household size, temperature and temperature. Akter & Bennett (2009) further showed that exposure to mass media enhances awareness and concern about the damage associated with climate change.

CHAPTER 3 : METHODOLOGY

This chapter presents the conceptual and theoretical framework used in the study. It further presents methods used in empirical analysis (ordered probit analysis and multivariate regression analysis). Description of the study area as well as sampling design and data collection are also presented in this chapter.

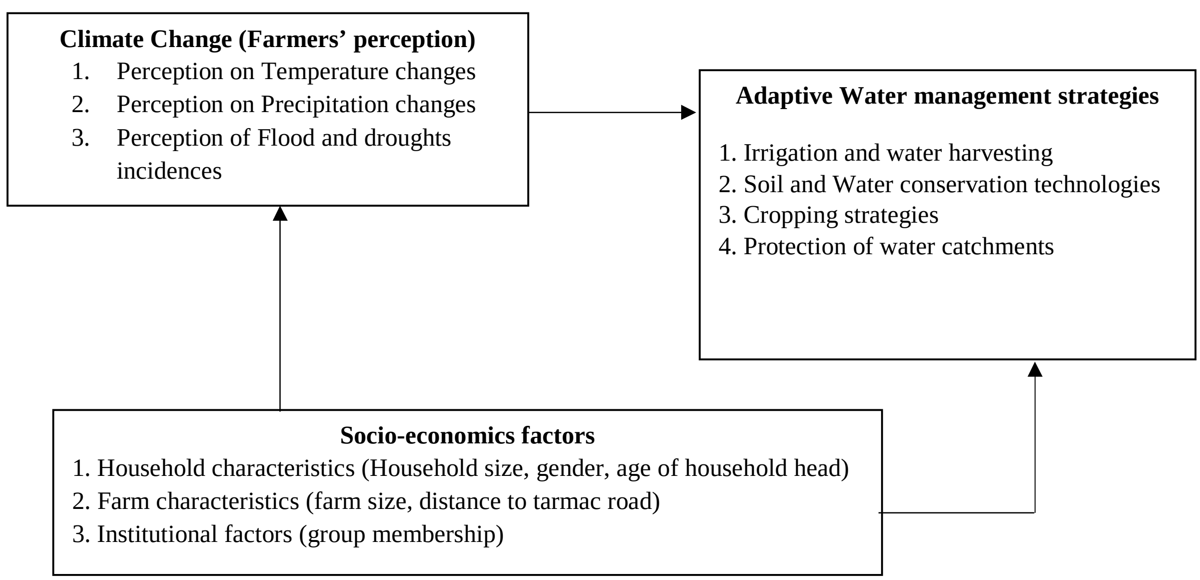
3.1 Conceptual Framework

The conceptual framework (figure3-1 see page 22) in this study shows the linkage between climate change perceptions, farm level water resources and adaptive water management strategies by crop farmers in Kakamega County. The study conceptualised that increase in atmospheric greenhouse gases (GHGs) and other natural causes such as solar variation and volcanic activities has led to global changes in climate variables (IPCC, 2013). Consequently, the changes in climate variables have an impact on water available for crop production at farm level thus adversely affecting crop production.

The study hypothesized that climate change as perceived by farmers was a constraint in crop production and that, farmers' perceptions of the changes in climate were influenced by socio economic factors. Climate change causes variations in a number of climate variables such as temperature, precipitation, wind speed, humidity, cloud and solar radiation which tend to affect water resources. It was assumed that the major changes that were likely to be perceived by farmers included changes in climate variables such as unpredictable rainfall patterns, increase in temperature as well as increased incidences of extreme climate events particularly floods and droughts. The study therefore needed to collect data on farmers' perception of climate change based on water resources at farm level. Data on household characteristics such as age, and farming experience of the household, as wells as data on farm characteristics and institutional characteristics like farm size, membership to farmer group and distance to the market were also needed.

The crop farmers affected by the declining water resources at farm level responded by undertaking various adaptive water management strategies. The study hypothesized that the adaptive water management strategies undertaken by farmers were influenced by socio-economic factors such as age, gender and access to extension services. The assumption was that, farmers adopt appropriate adaptive water management strategies to reduce climate change vulnerability. In addition, some adaptive water management practices such as irrigation and soil water conservation technology directly improve agricultural production. Data on adaptive water management strategies that farmers have adopted, household characteristics and farm characteristics were required to achieve the study's objective.

Figure 3-1 : Conceptual framework



3.3 Theoretical Framework

This study uses theoretical framework from the utility maximization theory. Based on random utility theory, a random utility model (RUM) describes a choice decision in which individual i has a set of alternatives *j* from which to choose (McFadden, 1978). In this case, farmer i has a set of adaptive water management strategies j to choose from. An individual farmer chooses an alternative from the set of available alternatives that maximizes utility. Further, it was assumed that the farmer's utility is a function of farm and farmer characteristics thus the choice of farmers' adaptive water management strategies when affected by climate change in Kakamega County is dependent on the socio economic characteristics. The RUM is based on the notion that a farmer derives utility from choosing an adaptive water management strategy. The level of utility $\mathbf{U_i}$ from a specific choice is a latent variable known only to the decision maker (farmer) and observed through the choices made by the farmers denoted as $\mathbf{Y_i}$. In this case the choices will be the adaptive water management strategies.

A discrete choice model was used to analyse factors affecting farmers' perception of climate change on water resources as opposed to linear model since the dependent variable takes values that are not continuous but discrete in nature (Greene, 2000). Determinants of adaptive water management strategies chosen by a farmer were also analysed using the discrete choice model. It was assumed that strategies were as follows:

Let T_1= Cropping strategy

T_2 = Irrigation and water harvesting

With U_2 = Utility a farmer gets from using cropping strategy

U_2 = Utility a farmer gets from using irrigation and water harvesting techniques

Based on RUM, the farmer would adopt T_2 instead of T_1 if T_2 led to a higher utility than T_1 (Greene, 2003).

The utility derived from use of a given technology U_{ij}, can be expressed as the linear sum of two components; a deterministic part V_{ij}, that captures the observable components of the utility function and a random error term ε_{ij} that captures unobservable components of the function including measurement errors for the i^{th} household among j^{th} number of options (Greene, 2003) as follows:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \qquad 3.1$$

For instance, in this study a crop farmer who is the decision maker, chooses from a set of adaptive water management strategies to obtain some level of utility U_{ij}. The discrete choice model assumes that the farmer will choose from outcomes that maximizes utility. The deterministic part V_{ij}, is the linear combination of observed explanatory variables such as farm and farmer characteristics and estimated parameters of the observed explanatory variables. The stochastic error term includes all the unobserved variables which have an influence on the utility of choosing a specific water management adaptive strategy.

3.4 Empirical Model

3.4.1 Determinants of Farmers' Perception of Climate Change Effects on Water Resource at Farm-Level in Kakamega County (Objective 1)

Past studies have been done on climate change perception of farmers. Kitinya *et al* (2012) used descriptive analysis to assess farmers' perceptions, experiences, and adaptation strategies to climate change and variability in Makueni County. Benedicta *et al* (2010) employed logit to evaluate farmers' perception and adaptation to climate change and investigated the factors and barriers that affected the adaptation processes in Sekyedumase district in Ghana. Guthiga *et al* (2008) used ordered probit to assess the level of satisfaction of management approaches in Kakamega forest. This study employed ordered probit to assess farmers' perceptions based on on-farm water resources.

To ascertain perceived impact of climate change on water resources at farm-level, respondents were asked to rate the severity of climate change effects on water resources in terms of climate change perception levels using a five point Likert scale. The Likert scale is used to measure attitudinal responses from respondents usually in a scale and ordinal in nature (Likert, 1932). The likert scale was as follows 1 = Strongly disagree, 2 = Disagree, 3=Somewhat agree 4 = Agree, and 5 =. Strongly agree. The responses (the dependent variable) were therefore ordered and discrete, making ordered probit model the appropriate for the empirical estimation (Greene, 2003).

Ordered probit model assumes that the value of the dependent variable Y_i^* is unobservable. The ordered probit presumes an underlying utility function:

$$Y_{im}^* = X_{im}\beta + \varepsilon_{im} \qquad 3.2$$

Where;

Y_{im}^*= The latent unobserved variable that corresponds climate change perception level,

X_{im}= The is a vector of socio-economic characteristics of the i^{th} observation,

β = The unknown parameter to be estimated, while,

ε_{im}= The random term of the latent utility function.

Following (Greene, 2003) Y_{im}^* is unobservable and we therefore observe:

$$Y_i = \begin{cases} 0 \;\; if\; Y_{im}^* \le 0 \\ 1 \;\; if\; Y_{im}^* 0 \le Y_{im}^* \le \mu_1 \\ 2 \;\; if\; \mu_1 \le Y_{im}^* \le \mu_2 \end{cases} \qquad 3.3$$

Where Y_i = when a farmers ‘agrees’, ‘somewhat agrees’ or ‘disagrees’ with perception statement that climate change is affecting water resources at farm level

The μ_s are unknown parameters which are jointly estimated with β-coefficients. It assumed that the random term of the ordered probit model follows a standard normal distribution. The model is estimated using maximum likelihood estimation methods with the probability specified as follows:

$$P(y = 0|X) = F(-\beta X_I), \qquad 3.4$$

$$P(y = 1{:}\,|X) = F(\mu_1 - \beta X_I) - F(-\beta X_I),$$

$$P(y = 2|X) = F(\mu_2 - \beta X_I) - F(\mu_1 - \beta X_I)$$

Where F (·) = The cumulative standard normal distribution function

P (.) = Probability of farmer choosing either ‘agree’, ‘somewhat agree’ or ‘disagree’ given the X variables

X = Vector of independent variables that affect the farmers perceptions levels

β = Vector of unknown parameters to be estimated

Marginal Effect

Ordered probit model is a nonlinear regression model and therefore, the coefficients are not marginal changes in dependent variables as independent variables change as commonly interpreted in OLS. To evaluate marginal change in an ordered probit model, marginal effects are calculated. The marginal effects were computed as follows:

$$\frac{\partial p(y = 1|X)}{\partial X_j} = f(\mu_1 - X_i\beta)\beta_j \qquad 3.5$$

$$\frac{\partial p(y = 2|X)}{\partial X_j} = f(\mu_1 \;\; X_i\beta)\beta_j \quad f(\mu_2 \;\; X_i\beta)\beta_j$$

$$\frac{\partial p(y = 3|X)}{\partial X_j} = f(\mu_2 - X_i\beta)\beta_j - f(\mu_3 - X_i\beta)$$

Where f (.) is a density function of a standard normal variable.

$$\frac{\partial p(.)}{\partial X_j} = \text{the change in Y given X as independent variable of the jth probability}$$

The marginal effects for dummy variables are calculated as the difference between the two resulting probabilities when the dummy variables equals to two values, 0 and 1.

3.4.2 Characteristic of Adaptive Water Management Strategies Adopted by Farmers with Special Reference to Perception of Climate Change in Kakamega County (Objective 2)

In order to characterize the adaptive water management strategies, only water management strategies undertaken as response to climate change by the crop farmers were identified and described in the area of study. The strategies that conserve soil moisture, increase water availability and those that manage excess water (such as flooding) were identified. Mean and percentages of interviewed household were used to show variations in adaptive water management strategies practiced by farmers. Graphical analyses and frequency distributions were used to present the qualitative information.

3.4.3 Determinants of adaptive water management strategies undertaken by farmers in Kakamega County (Objective 3)

Studies such as Deressa (2009) and Nabikolo *et al*, (2012) have assessed the determinants of adaptation to climate change using heckman model and logit regression model respectively.

Multinomial logit (MNL) and multinomial probit (MNP) models are mainly used in analyses where the decision variable has more than two choice options. For instance, Nhemachena & Hassan, (2007) assessed determinants of climate adaptation measures in sub Saharan Africa using the MNL model. This study however used multivariate probit model (MVP) to analyse determinants of adaptive water management strategies. As opposed to MNP and MNL. The

MVP model allows for simultaneous adoption of adaptive water management strategies by farmers and to allow potential correlation in the adoption decisions (Marenya & Barrett, 2007; Belderbos *et al*., 2004; Kassie *et al*., 2013). The model is appropriate since farmers tend to adopt various adaptive water management options simultaneously, as they respond to numerous agricultural production constraints caused by adverse effects of climate change on farm level water resources. The MVP is an extension of the bivariate probit and uses Monte Carlo simulation techniques to jointly estimate the multiple probit equation system (Geweke, 1989). The MVP model is specified as follows:

$$y_i = 1 \text{ if } X^i\beta_i + \varepsilon_i > 0; \qquad 3.6$$

$$y_i = 0 \text{ if } X^i\beta_i + \varepsilon_i \leq 0$$

Where:

y_{ij} = represents unobservable latent variable of adaptive water management for farmer i.

X = a vector observed variables that affect the adaptation decisions of the adaptive water management strategies.

β_i = a vector of unknown parameters to be estimated.

ε_i =a vector of random error terms distributed as multivariate normal distribution with zero mean and a covariance matrix with diagonal elements equal to one (Cappellari & Jenkins, 2003).

3.5. Explanation of variables and there expected signs

i. Age, Farming Experience

Age and farming experience were hypothesised to have positive and negative effect on adaptation. The results of some studies showed age and farming experience have significant and positive influence on adaptation (Nhemachena & Hassan (2007). Other studies have shown age having a negative influence on adaptation (Nyangena, 2007; Bekele & Drake, 2003). Older farmers may have been exposed to production technologies and also accumulate capital to easily undertake adaptive water management technologies. However it is also expected that older farmers may be less willing to take up risks on the new technologies and may also lack energy to adopt the technologies.

ii. Household Size

Past studies have shown that household size has a positive effect on adoption (Anley *et al*, 2007; Nyangena, 2007). Larger household size may provide necessary labour required given that some of the adaptive water management are labour intensive. Most farmers in rural areas are not able to hire labour and they largely depend family labour. Therefore the study hypothesised that household size may have positive effect adaptive water management technologies.

iii. Gender of household head

The study hypothesised that gender of the household head is likely to have a significant effect on perception and adaptation because of the different roles played by men and women in the society thus differences in access to resources and information. Women, particularly in rural areas have less access to resources such as land and income and wealth. Women also have less access to information and education (Kaliba *et al.,* 2000).

iv. Education

Previous studies show that education may influence farmers' perceptions as well as adoption of technology (Tologbonse, *et al.*, 2010; Maddison, 2006; Deressa *et al*, 2009). More educated farmers have greater ability acquire knowledge on climate change and technologies that may help in adoption of adaptive water management. Thus, farmers with higher level of education are more aware of climate change and can easily understand the appropriate technologies of adaptive water management. It was expected that education will have positive and significant influence on perception of climate change based on water resources and adoption of adaptive water management strategies.

v. Access to information

Access to information through extension is associated with higher likelihood of perceiving and adapting to climate change (Maddison, 2006; Deressa *et al*., 2009; Nhemachena & Hassan, 2007). Access to climate change information would create more awareness thus higher climate change perceptions among farmers (Bradshaw *et al*., 2004). The study therefore assumed that, farmers with better access to climate information through radio or extension services were more likely to perceive that climate change effects on water resources (Bryan *et al*., 2009).

vi. Market Access

Market access is a significant factor in perception of climate change as well as adaptation. Markets plays important role in terms of availability of support services such as farm inputs, credit organizations, availability of information and an indicator of transaction costs. (Lapar & Pandely 1999; Mano et al., 2003). Past studies indicate that distance to produce market, input market and tarmac were significant adoption of technologies such as soil and water conservation technologies (Nyangena, 2007; Madison, 2006).This study expected negative and significant effect of distance to the nearest produce and input marfket as well as distance the nearest tarmac road since it was assumed that households closer to the market and tarmac road have better access to the market and could better perceive and adapt to the impacts of climate change based on on-farm water resources.

vii. Resource Endowment

Access to economic resource was represented by variables such as wealth index, Farm size household's annual income, and access to credit. Farmers with better access to financial resources can easily buy inputs that are necessary in adoption of adaptive water management technologies. Therefore, it was hypothesised that farmers with better access to economic resources have a priori positive sign. For example, Knowler and Bradshaw (2007) indicated that household's wellbeing had a positive influence on adoption of agricultural technologies. Asfaw *et al*. (2014) also showed that wealth of the farmer increased the likelihood of sustainable land management technologies. Large farm size is associated with greater wealth thus it may have a positive effects on adaptive water management.

viii. Social Capital

This study defines social capital as inherent resources that exist in social relations which can enhance collective action. Membership to a farmer group was used as a proxy to social capital. Membership to a farmer group may enhance climate change perceptions as well as positively influencing adaptive water management strategy as hypothesised by the study. For instance, Adger (2003) reported that social capital enabled people to collectively cope with climate risks. Other studies have shown that membership to a farmer group can increase climate change perception and adaptation (Deressa *et al.,* 2009; Nyangena, 2007). Farmer group can be a source of alternative credit to farmers through informal saving and credit services and at the same time facilitate exchange of information and technology.

Table 3.1: Description of explanatory variables and their expected signs for Ordered probit and Multivariate probit models

Variable	Description and Measure of the variables	Expected sign
Age	Age of the farm household head (years)	+ /-
Household size	Number of people in the household	+ / -
Gender of household head	Dummy variable 1 = Male, 0 = Female	+
Education level	Number of years in formal education	+
Main occupation	Main occupation of household head 1 = Farming 0 = Otherwise	+
Farming experience	Number of years of farming as a household head	+/-
Farm size	Size of the farm in acres	+
Extension	If household has access to any extension services 1 = Yes, 0 = No	+
Distance_ tarmac	Distance in kilometres to the nearest tarmac road	-
Distance_ water source	Distance in kilometres to the nearest water source	-
Distance_ produce market	Distance in kilometres to the produce nearest market	-
Credit	If household has access to credit from any source in the last three years 1 =Yes, 0 = No	+
Group member	if a household head is a member of a farmer group 1 = Yes 0 = Otherwise	+
Climate information-	If household has access to climate information 1 = Yes, 0 = No	+
Wealth status	An index constructed using household asset ownership using principal component analysis (PCA)	+
Perception	Farmer perception to changes in climate variables	+
Household income	Annual income of the household	+

3.5 Study Area

The study was conducted in Lugari Sub-County, Kakamega County in Western Kenya. The region was selected owing to its fragility and sensitivity to climate variability (GoK, 2012b). Lugari sub -county borders Bungoma County to the west, Uasin Gishu County to the East and Trans-Nzoia County to the north. It occupies an area of 368.2 km^2 and is divided into two administrative Divisions namely; Lugari and Matete. Lugari division occupies an area of 266.3 km^2 with four locations and eight sub-locations while Matete division has an area of 101.9 Km^2 with two Locations and seven sub-locations. Lugari sub-county lies at an altitude of between 1600-1999 m above sea level and between longitude $34^0$28'and 35^0 East and between latitude $0^0$25' and 1^0 North of the Equator. Climate and rainfall pattern are largely equatorial type with temperatures between 6 –24 degrees centigrade. The annual rainfall averages 1100-1600 mm distributed between two seasons of March to July and September to November. Late November to late February or early March is traditionally the long dry season, and mid-June to late July is the short one. This however has become variable with frequent drought spells in between (GoK, 2012 a).

The sub-county is divided in two agro ecological zones, that is, the Upper Midland zone (UM_{3-4}) and the Lower Midland zone (LM_{3-4}). Lugari Division lies in the Upper Midland zone where intensive maize farming is the common crop enterprise whereas Matete Division lies in the Lower Midland zone where maize and sugarcane farming are the main crop enterprises. Crop production and pasture for livestock are the main agricultural land uses. Maize and bean cultivation is for both commercial and subsistence while coffee, sugarcane and sunflower are the main cash crops in the study area. Livestock production is also common the area of study.

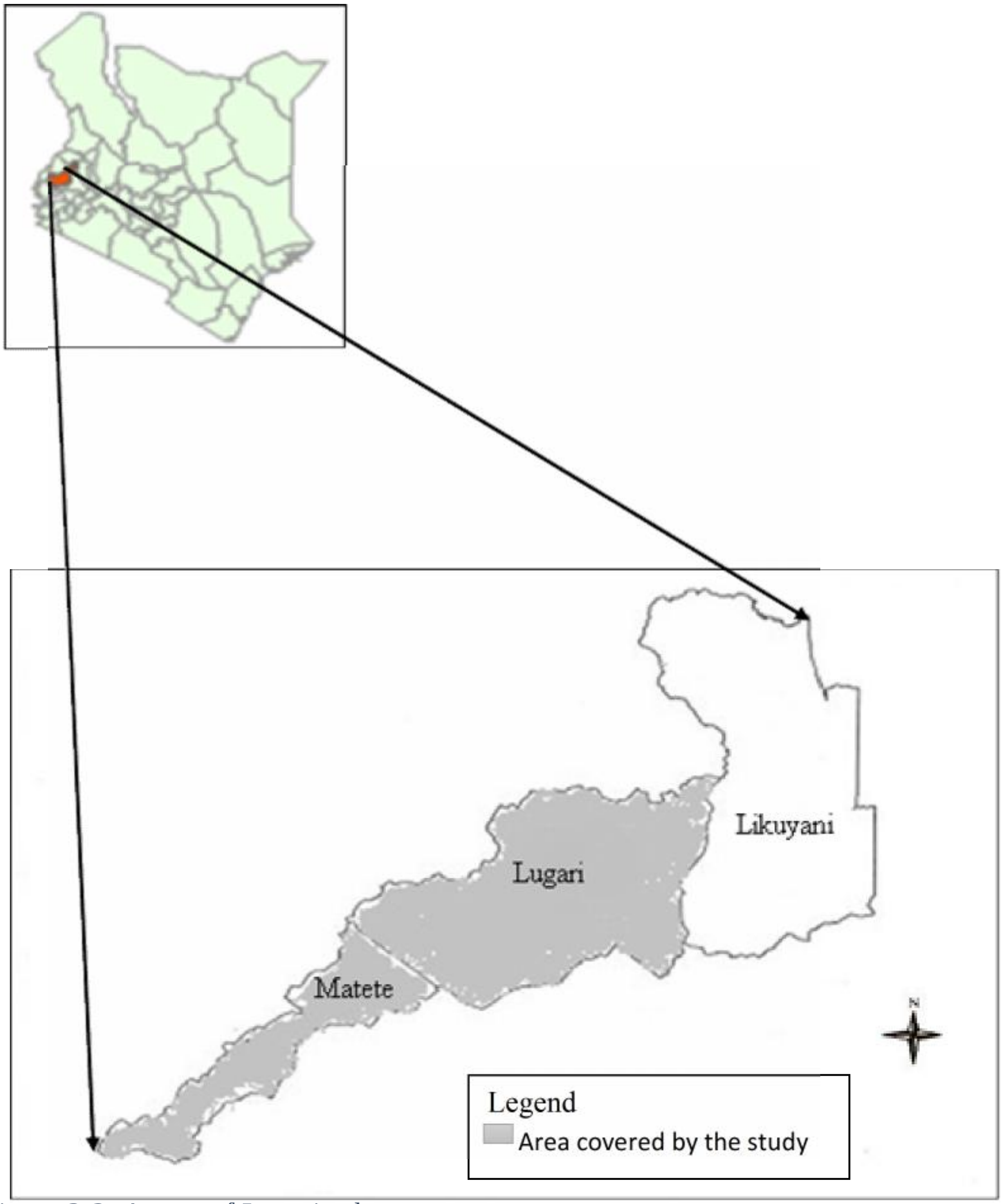


Figure 3-2: A map of Lugari sub-county

3.5 Sample Size Determination

According to Cochran (1963), the following formula was used to determine sample size.

$$N = \frac{z^2 pq}{e^2} \quad 3.7$$

Where;

N = the sample size to be determined,

Z =the absciss a of the normal curve that cuts off an area at the tail of a normal distribution curve,

e = the desired level of precision,

p = the estimated proportion of the target population that has an attribute the study is interested in. (In this case the attribute was farmers, where 90% of Lugari sub county residents are farmers (GoK, 2012b))

$q \ = (1 - p)$.

$$\frac{1.96^2(0.9)(0.1)}{0.05^2} = 139$$

Therefore, at least 139 complete questionnaires were targeted during the data collection.

3.6 Sampling Design

Multistage sampling technique was used in the study. Lugari Sub County in Kakamega County was purposively selected due to the increased occurrences of droughts, floods and erratic rainfall associated with climate change (GoK, 2012b). Radom sampling was used to select locations in the Sub County were four locations were randomly selected namely, Mautuma, Chekalini, Lugari and Chevaywa. Systematic random sampling was used to select households where every fourth household was selected from either side of the road in the villages.

3.7 Data Collection

The study used primary data collected using semi structured questionnaires. Five enumerators were selected and trained. Secondary data were obtained from publications, seasonal annual reports of the county, and relevant government ministries documents. A pre survey was carried out to have a broader understanding of the study area. Prior to the actual survey, four focus group discussions were carried out to obtain background information on climate change and adaptive water management options. Pretesting of the questionnaire was also conducted which helped to make necessary adjustments of the questionnaire.

3.8 Data Analysis

Data were entered using Statistical Package for Social Sciences (SPSS) while Stata was used for analysis in both descriptive statistics and econometric models. For the descriptive statistics, frequency distributions, percentage and means were used to present the results.

CHAPTER 4 : RESULTS AND DISCUSSION

This chapter presents an overview of the selected farm and household characteristics of the interviewed respondents. The results of ordered probit and multivariate probit regression analysis as well as characterization of adaptive water management undertaken by farmers in Lugari sub-county are also discussed in this chapter.

4.1 Descriptive Statistics for Independent Variables used in Ordered probit and Multivariate Probit Regression Analyses

This section presents a summary of descriptive statistics used in both ordered probit and multivariate probit of the study. Data on household characteristics, farm characteristics and institutional factors were analysed and presented through means percentages, range and frequencies as shown in Table 4.1. Majority of the households were headed by men (84 percent). On average, a household had 6 members with a minimum family size of 1 person and a maximum of 10 people. This was higher than the national average household size of 4.3 (GoK, 2010b).

The average age of the household head was 52 years with the range of 28 to 82 years. The result is comparable to the national average age (57 years) of a farmer in Kenya (Momanyi *et al.*, 2012). Moreover, the average years of farming experience of the household head was 22 years, which implies that very few young household heads are engaging in farming as an economic activity in the study area. This may be attributed to lack of access of agricultural land among the young people. Majority of the respondents had secondary education (49 percent), followed by primary education (34 percent). Few farmers had attained tertiary education (11 percent) and only 6 percent of the respondents had no formal education. Generally, the education level of the household head was better than the national average.

About half of the respondents had attained secondary education compared to the national average of about 18 percent (KNBS, 2013). This is an indication that the farmers may have greater ability to adopt to new adaptive water management technologies.

Table 4.1: Selected farm and household characteristics of farmers in Lugari sub-county

Variable	Mean (Std dev.) n=159	Percentage (%) n=159
Household size	5.91(2.5)	
Age (years)	52.1 (12.4)	
Male		84.3
Income (Kshs)	255340 (2844890)	
Education (years)	9.4 (3.9)	
Credit access		28.3
Farming Experience (years)	22.2(12.2)	
Farm size (acres)	5.6 (10.1)	
Extension		48.4
Group member		61.6
Produce market distance (km)	4.8 (5.5)	
Tarmac road (km)	7.5 (5.01)	5.0
Water Distance (km)	0.36 (0.8)	0.8

Source: Author’s survey, 2014

The average farm size was 5.2 acres, with a minimum of 0.25 acres and a maximum 53 acres. Most of the respondents (76 percent) had less than 5 acres of land. Smallholder farmers are defined, as those with operating less than 5 acres of cropland (World Bank, 2003), which means that the majority of the farmers interviewed were smallholder farmers. The average distance to main water source was 0.32 kilometres, implying that most farmers are close to the water source. This is because that the main source of water for about half of interviewed farmers (54 percent) was hand dug wells, often at the homestead. The average distance to both input and produce market was approximately 5 kilometres. Most farms were located far away from the tarmac roads, because the average distance to the tarmac roads was 5.01 kilometres. The implication of the distance is transaction costs related to the market may acts as a barrier to access input and output markets. Majority of respondents (72 percent) had no access to credit for the last three years, suggesting poor access to financial services likely to limit famers' investment in farming (Gbetibouo, 2009). Further, the results show that about half of the respondents (48 percent) had contact with the extension officers, therefore extension can be used to disseminate climate change information and Household heads who belonged to farmer's group were the majority at 62 percent. The farmer group provided pooled farm labour services such as planting and harvesting, farmer groups also enabled farmers to save money and get credit commonly referred as '*merry go round*' and '*table banking*'. Membership to a group can be beneficial because individual farmers can easily access credit, agricultural information as well as access to the market through the farmer groups.

4.3 Determinants of Climate Change Perception on Water Resources at Farm-Level

To achieve objective one of the study, an ordered probit regression (Appendix III) was estimated to determine factors influencing farmer's perception of climate change effects on water resources at farm level. Multicollinearity, goodness of fit, and specification tests were carried out. Heteroskedasticity was tested using Breusch-Pagan test and the presence of heterscedasticity was addressed by estimating a robust model (StataCorp, 2013; Hassan and Nhemachena, 2008). The existence of multicollinearity was ruled out using Variance

Inflation Factor (VIF) since all the explanatory variables had a VIF less than 2, with a mean VIF of 1.23 (see Appendix I). Multicollinearity is present in a model if VIF is greater than 10 (Gujarati, 2004). The chi-square value for log likelihood function was also highly significant indicating that all the coefficients of explanatory variables in the model were significantly different from zero. To test for model specification, link test was carried out (Appendix II). The Link test is based on the idea of regression specification. It tests whether the variables are correctly specified or there is need for additional explanatory variables. The dependent variable is regressed with the hat and hat squared. Hat is the predicted values from the prior executed regression model. In Stata, it is the significance of hat squared that is interpreted. If the p-value of hat squared is significant, the null hypothesis is rejected and conclude that our model is not correctly specified. In this model the hat-squared was not significant therefore we fail to reject the null hypothesis and conclude that the model is correctly specified. (StataCorp, 2013).

From the five level of perceptions, “strongly disagree”, “disagree”, “somewhat agree”, “agree” and “strongly disagree”, ordered probit regression was done (Appendix III) and the marginal effects were computed for only three level of perception out of the possible five levels. This was due to no response or very few respondents assigning those specific levels of perception to climate change. In particular, there was no response for “strongly disagree” category while only three out of 159 respondents chose “strongly agree” as their level of perception. Hence, the three categories that were used are; “disagree”, “somewhat agree” and “agree”. In ordered probit, the marginal effects are interpreted as effects of changes in the independent variables on the predicted probabilities of being under one category (such as “disagree”) of the dependent variable (Table 4.2).

Table 4.2: Ordered probit marginal effects for the three levels of climate change perception on water resources among farmers

Variable	Disagree		Somewhat agree		Agree	
	dy/dx	P level	dy/dx	P level	dy/dx	P level
Age	-0.001	0.342	-0.002	0.330	0.003	0.327
	(0.001)		(0.003)		(0.003)	
Gender	-0.080*	0.096	-0.169***	0.003	0.240***	0.009
	(0.048)		(0.057)		(0.092)	
Household size	0.005	0.191	0.019	0.165	-0.023	0.156
	(0.004)		(0.014)		(0.016)	
Education	-0.001	0.445	-0.006	0.460	0.007	0.453
	(0.002)		(0.008)		(0.009)	
Main Occupation	-0.023	0.306	-0.080	0.214	0.098	0.229
	(0.023)		(0.064)		(0.082)	
Farm size	-0.002*	0.061	-0.008**	0.029	0.010**	0.025
	(0.001)		(0.004)		(0.004)	
Water Distance	0.033***	0.009	0.126***	0.002	-0.150***	0.001
	(0.013)		(0.041)		(0.044)	
Tarmac Road	-0.001	0.436	-0.006	0.406	0.007	0.409
	(0.002)		(0.007)		(0.008)	
Produce Market	-0.012	0.230	-0.047	0.277	0.057	0.261
	(0.010)		(0.044)		(0.050)	
Extension	-0.028	0.101	-0.108*	0.084	0.128*	0.077
	(0.017)		(0.062)		(0.073)	
Farmers Experience	0.018	0.525	0.088	0.625	-0.098	0.599
	(0.028)		(0.179)		(0.187)	
Information from Radio	-0.068**	0.039	-0.172***	0.004	0.231***	0.004
	(0.033)		(0.059)		(0.080)	
Wealth Index	-0.013***	0.009	-0.049***	0.001	0.059***	0.000
	(0.005)		(0.015)		(0.017)	

*significant at 10%, ** significant at 5%, *** significant at 1% respectively

Figures in parentheses are the standard errors

In general, gender, farm size, distance to the main source of water, contact with an extension officer, access to climate change information through radio and wealth status, significantly explained the level of climate change perception based on water resources. The probability of agreeing that climate change affects water resources increased by about 24 percent in men heading household, whereas the probability of both disagreeing and somewhat agreeing to climate change perception on water resources decreased by 8 percent and 17 percent respectively among men headed households. This is possibly due to the different gender roles of both men and women which exposes men to higher possibility of acquiring information on climate change and consequently affecting the climate change perception. For instance, women are always restricted to household chores and on-farm labour while men are often engaged in non-farm labour. Similar result was reported by Ndambiri *et al*. (2012) who found that perception of climate change was higher for men heading households than women heading households. This implies that policies should be designed and implemented in such a manner that would lead to greater equity and equality by taking into consideration the adaptive capacity of both men and women in relations to the gender their gender roles.

Respondents with larger farm size were more likely to agree that climate change is affecting water resources at farm level by 1 percent. While an increase in farm size by an acre of land reduced the probability of farmers disagreeing and being neutral to perception of climate change on water resources by 0.2 percent and 0.8 percent respectively. The possible explanation is that a farmer with a larger piece of land would experience greater loss caused by climate change effects on water resource than farmers with smaller pieces of land leading to higher perceptions. With the looming water scarcity at the farm level, farmers with larger pieces of land may not be able to maintain farm productivity leading to yield reductions. This implies that perceptions depends on the impact of the climate risk to the farmer, therefore awareness of climate change and promotion of adaptive technologies by the Kenya government should consider the exposure the farmer towards the climate change risks.

Proximity to the water source significantly influenced climate change perception among crop farmers. Contrary to expectation, a kilometre increase in distance to main water source increased the probability of a farmer to both disagree and somewhat agree to the perception of climate change by 3 percent and 12.6 percent respectively, but reduced the probability of respondent to agree that climate change affects water resources by 15 percent. Plausible explanation is that farmers nearer the water sources (mainly hand dug wells and springs) may have noticed more reduction of water caused by climate change effects compared to the farmers who are further from the water sources who may hardly attribute degradation of water resources to the effect of climate change This is helpful to the stakeholders such as government and non-governmental organization who can ensure that distance to a water source from the farm is considered in the implementation of policies such as protection of water catchment that can enhance water availability among farmers.

Farmers who had contact with an extension officer were likely to agree that climate change affects water resources by about 13 percent. Similarly, contact with an extension officer reduced the probability of a farmer being neutral to the perception of climate change on water resources by about 11 percent. Extension services accelerates information dissemination to the farmers therefore those who had contact with extension officers could easily have access to climate change information. The results are comparable to those of Nhemachena & Hassan (2007) who found that access to free extension services increases the awareness of changing climatic conditions as wells as the probability of taking up adaptation measures in response to the changing climate in Southern Africa. Similar study by Bryan *et al*., (2009) showed that access to extension services had a positive influence on climate change adaptation. Since extension services plays and important role in creating awareness of climate change and consequently in the adoption of adaptive practices, the Kenya government should invest in extension services by increasing the ratio of extension staff to farmer. This is likely to enhance effectiveness of climate change information dissemination to the farmers.

As expected, access to climate change information through radio had significant and negative effect on probability of a farmer to both disagree and being neutral to climate change perception by 7 percent and 17 percent respectively. Likewise, access to climate change information through radio increased the probability of a farmer agreeing that climate change affects water resources at farm level by about 23 percent. A study by Mano and Nhemachena (2006) in Zimbabwe also showed that access to weather information is key in shaping farmers' perception of climate change. Mass media such as radio therefore plays an important role in the dissemination of climate change information. Access to climate information through radio had a positive influence on the perception of climate change based on on-farm water resources in the study area. A combination of extension services with radio programs would be more effective in the dissemination of climate change information, adaptive water management technologies.

Wealth status also influenced climate change perception on water resources at farm level. The probability of a farmer agreeing that climate change affected water resources increased with the wealth status of the farmer by about 6 percent. Wealth status also negatively influenced the probability of a farmer disagreeing or being neutral by about 1 percent and 5 percent respectively. This therefore means that farmers who are well off were more likely to perceive climate change effects on water resources than poor farmers. The result supports Deressa *et al*. (2008) findings that wealth had significant effect on farmers' perceptions of climate change in Nile basin, Ethiopia. Since wealthier farmers tend to have better access to information and greater access to technology, the Kenya government should put policies that will increase access to resources

4.4. Characterization of Adaptive Water Management Strategies Adopted by Farmers in the Face of Climate Change in Kakamega County

To achieve the second objective of the study, characterisation of adaptive water management strategies was done. The practises identified were broadly categorised as cropping strategy, irrigation and water harvesting (IWH), soil and water conservation (SWC) techniques and water catchment protection. Cropping strategy included planting drought tolerant crops, drought tolerant maize variety and planting flood tolerant maize variety. For IWH, the adaptive practices stated were irrigation, water harvesting and sinking borehole to supplement water for irrigation. Soil and water conservation techniques practiced in the area of study were mulching, planting of cover crops, constructing ridges, bunds and stone lines, digging trenches and planting trees to prevent soil erosion. Lastly, protection of water catchment was also practised. Other variables such as age, main occupation and distance to the tarmac road had no significant effect on climate change perception based on water resources as hypothesised.

4.4.1 Cropping Strategy Techniques

Cropping strategy was commonly used by farmers due to highly erratic rainfall experienced in the study area. The study found that among the cropping strategy techniques used by surveyed farmers, planting of drought tolerant maize variety was the most practiced (47.2 percent).The other common practice was planting of other drought tolerant crops like sweet potatoes, millet and cassava where 45.3 percent of surveyed farmers reported it as an important adaptive strategy. Both planting drought tolerant maize variety and other drought tolerant crops were reported to be helpful in coping with increased temperature and water stress. Only 9.4 percent of the respondents planted flood tolerant maize variety despite increased occurrences of heavy rains that cause flooding and water logging.

4.4.2. Irrigation and Water Harvesting (IWH)

As summarized in table 4.3, farmers reported IWH as an important adaptive water management strategy. It is important to note that irrigation was in small scale mainly on vegetables other than on maize which was the staple crop in the area. About 2.7 percent of farmers started irrigation due to increased cases of prolonged dry spell, while 5.7 percent who had already started irrigation shifted to improved irrigation (drip irrigation) to enhance water use efficiency for crop production during dry seasons. According to Kenya Vision 2030, improved irrigation is significant in increasing farm productivity particularly with expected increase water scarcity (GoK, 2008).

However, improved irrigation technologies such as drip irrigation were the least common. This could be attributed to lack of knowledge of improved irrigation technologies and high capital needs (Deressa *et al*., 2008). Water storage in tanks and rain water harvesting such as roof water harvesting for agricultural use were also limited. For instance, 6.9 and 11.3 percent of interviewed farmers practiced water storage and rain water harvesting respectively.

Table 4.3: Proportion of farmers using Irrigation and Water harvesting techniques in Lugari Sub County

Irrigation and water storage	Percentage
Started irrigation	2.7
Improved existing irrigation	5.7
Water storage for agricultural use	6.9
Rain water harvesting	11.3
Water dams/pans for runoff water harvesting	6.9
Borehole/wells	19.5

Source: Author's survey, 2014

These practices are uncommon due to high initial costs and lack of promotion of these technologies in the study area. The results also shows that 19 percent of the surveyed farmers dug wells as a source of irrigation water due to increased water scarcity caused by increased cases of prolonged droughts.

4.4.2.1 The Main Sources of Irrigation Water and Type of Irrigation Practiced

The farmers who practiced irrigation as an adaptive strategy were subsequently asked to state their main source of irrigation water and the method of irrigation practiced. The three main sources of irrigation water were river or stream, well or borehole and piped water. Borehole or well was the most common source of irrigation water (79.5 percent) It was also noted that ground water from wells and boreholes only supplemented water demands during prolonged dry seasons where farmers mainly depend on rain fed agriculture. Most hand dug wells were dug by individual households whereas boreholes were largely communal, sunk by non-governmental organizations (NGOs) operating in the study area. The other source sources of irrigation water were rivers and streams (15.4 percent) and piped water which is mainly from the rivers (5.1 percent).

4.4.2.2 Methods of Irrigation Practised by Farmers

The three main methods of irrigation mentioned were; watering can, water pump and drip irrigation. The most common method of irrigation was by use of watering can (74.4 percent) while approximately 18 percent of farmers irrigated using water pumps. The least practised method of irrigation was drip irrigation where only 7.7 percent of farmers used it. In 2005, the Government of Kenya identified drip irrigation among other prioritized technologies to be disseminated to small scale farmers as an adaptive strategy to climate change in both agriculture and water sectors (GoK, 2012 a). Moreover, Woltering *et al*. (2011) in comparing drip irrigation and watering cans, on-station trials showed that drip irrigation achieved greater yield and better returns to water. Despite the benefits of drip irrigation, majority of farmers being resource-poor is the likely be the reason for very low use of drip irrigation.

4.4.3 Soil and Water Conservation Techniques Used by Farmers in Lugari Sub County

Table 4.4 presents various soil and water conservation (SWC) techniques that were adopted by farmers in response to climate risks that affect water resources at farm level. Most farmers stated that SWC techniques were practised either to reduce flooding, increase soil fertility or conserve moisture. Mulching involved application of crop residues on soil surface mainly for moisture retention which complemented the small scale irrigation practiced in vegetable farming. Mulching was also reported to increase soil fertility and at the same time reduce soil erosion (Adejuwon, 2008).

Table 4.4: Proportion of farmers using soil and water conservation techniques in Lugari Sub County

Soil and water conservation	Percentage of farmers using the technique
Mulching	44.0.
Planting cover crops	37.7
Building ridges and bunds	28.3
Drainage trenches	37.1
Introduced stone lines	8.2
Plant trees to reduce soil erosion	42.1

Source: Author's survey, 2014

Similarly, planting of cover crops was also used for soil moisture retention and reduction of soil erosion especially during heavy rains as indicated by Zhang *et al*. (2007). Temporary soil bunds was used mainly for water retention water during short rain season when water was scarce especially in sweet potato farming. This supports the findings of a study by Kato *et al*. (2009) that stone bunds and soil bunds increased water retention in low rainfall areas. Existing adaptive strategies that were used to reduce risks from rain water runoff (flooding, soil erosion) were planting trees, construction of stone lines and using drainage trenches. Planting trees on the farm has shown to reduce soil erosion by holding together soil particles (Bregman, 1993). Though uncommonly practised, some farmers (8.2 percent) reported stoneline as a SWC technology used while drainage trenches were mainly used to divert excess rain water from the farm.

4.4.4 Protection of Water Catchment as an Adaptive Strategy in Lugari Sub-County

Water catchment protection in this study was considered as actions undertaken by the farmers to prevent destruction of areas perceived to retain rainwater and feed into a water sources. The common activities reported by farmers were tree planting and reduced agricultural activities in the catchment areas. About 19 percent of interviewed farmers reported protection of water catchment as an adaptive strategy. This shows that very few farmers are consider protection of water catchment as an adaptive water management strategy. There is need for government and non-government organization to promote water catchment protection as an adaptive strategy in the study area. According to National Climate Change Response Strategy, degradation of water catchment leads to reduction of water flow from springs and streams, fall of water table, soil erosion and increased cases of flash floods. Therefore, protection of water catchment should be promoted in the study area since it enhances climate risk resilience to crop farmers by ensuring regular flow of rivers thus sustained water availability for agriculture as well as reducing flooding and erosion.

4.5 Determinants of Adaptive Water Management Strategies

To achieve the third objective of the study, multivariate probit was estimated to analyse determinants of adaptive water management strategies undertaken by farmers. Multivariate model jointly estimates multiple probit equations (Geweke, 1989). This study estimated four probit equations which include cropping strategy, irrigation and water harvesting, soil and water conservation and protection of water catchment. All the four probit equations were positively correlated which means the adaptive strategies were simultaneously adopted by farmers. The Wald test was significant (Prob > χ^2= 0.0000), and therefore, the hypothesis that all regression coefficient are jointly equal to zero was rejected. The correlation coefficients between the error terms of the adaptive water management equations are all significant as also shown in Table 4.5, further confirming the suitability of using multivariate probit model (Kassie *et al*., 2013; Marenya & Barrett, 2007). This means that the adaptive water management strategies were not mutually independent. Furthermore, all the adaptive water adaptive are complements as indicated by the positive correlation coefficients between the error terms of the equations.

Table 4.5: Correlation coefficients between error term of multivariate probit equation

	Cropping strategy	**Irrigation and Water harvesting (IWH)**	**Soil and water conservation (SWC)**
Cropping strategy			
Irrigation and Water harvesting (IWH)	0.417 (0.114)***		
Soil and water conservation (SWC)	0.339 (0.117)***	0.495 (0.108)***	
Protection of Water Catchment	0.250 (0.144)*	0.545 (0.146)***	0.806 (0.124)***

Prob > χ^2 = 0.0000, *significant at 10%, ** significant at 5%, *** significant at 1% respectively. Standard errors are in parenthesis

The result in Table 4.6, shows that adoption of Cropping strategy, IWH, SWC and protection of water catchment were influenced by socio economic characteristics and farmers' perception of climate change. Among the four adaptive water management strategies only protection of water catchment was significantly influenced by the age of the household head. The results further showed that older farmers were less likely to use protection of water catchment as a water adaptive strategy. Since protection of water catchment is considered a long term adaptive strategy, older farmers may not have an incentive to invest more in the adaptive strategy which will have an impact in future compared to younger farmers.

Table 4.6: Determinants of adaptive water management strategies among farmers in lugari sub county, multivariate probit model

	Cropping strategy		Irrigation and Water harvesting (IWH)		Soil and water conservation (SWC)		Protection of Water Catchment	
Variables	Coefficient	Robust Standard error	Coefficient.	Robust Standard error	Coefficient.	Robust Standard error.	Coefficient.	Robust Standard error
Age	-0.019	0.013	0.05	0.013	-0.010	0.013	-0.055***	0.018
Gender	-0.556	0.346	0.261	0.334	0.349	0.312	0.505	0.385
Farming experience	0.000	0.013	-0.006	0.014	0.013	0.014	0.062***	0.018
Farm size	-0.002	0.014	-0.068***	0.021	0.003	0.015	-0.040	0.030
Water source distance	0.119	0.160	-0.724**	0.301	0.126	0.191	0.542***	0.167
Produce market distance	0.028	0.028	0.082***	0.029	-0.043*	0.024	-0.059*	0.033
Tarmac road distance	-0.074***	0.026	-0.088***	0.026	-0.024	0.025	-0.001	0.024
Group member	-0.080	0.267	-0.540**	0.267	-0.174	0.298	0.780**	0.315
Extension	0.559**	0.249	0.427	0.268	-0.406	0.292	-0.009	0.313
Credit	0.182	0.278	-0.213	0.263	-0.042	0.282	-0.094	0.279
ln income	-0.015	0.124	0.064	0.105	0.198	0.125	0.164	0.145
Climate information_AEO	-0.102	0.233	0.282	0.239	0.833***	0.265	0.354	0.300
Increased flooding	0.097	0.083	-0.012	0.082	0.118	0.083	0.276***	0.079
Delay in onset rain	0.153*	0.093	0.052	0.097	-0.013	0.094	0.280**	0.112
Water_ degradation	-0.148*	0.089	-0.206**	0.105	0.212**	0.096	0.284***	0.107
Decreased rainfall	0.110	0.085	0.309****	0.086	-0.027	0.090	0.023	0.081
Constant	1.520	1.609	-0.728	1.417	-2.312	1.646	-5.378***	2.002

Number of observation =159 Wald $\chi^2(64)=236.08$ Log pseudo likelihood=-287.51331 Prob > $\chi^2=0.0000$

Farming experience increased the likelihood of the farmers to use protection of water catchment as a water management adaptive strategy. This result is consistent with the findings of Nhemachena & Hassan (2007), which indicated that farming experience increased the probability of a farmer adapting to climate change. This was mainly attributed to more knowledge on climate change by experienced farmers, who may have also acquired more skills over time to take up adaptive strategies against the impacts of climate change. Farm size had a negative and significant influence on use of IWH as an adaptive water management strategy. This is because IWH was mostly practiced at a very small scale by farmers who owned smaller pieces of land compared to farmers with larger farms. As noted by Marenya & Barrett (2007), this adaptive water management practice is influenced by the size of the farm.

Distance to the water source in this study is a proxy to farmers' access to an alternative water source (wells, boreholes, streams and rivers) other than rainwater. With declining on-farm water sources due to unreliable rainfall, exacerbated by climate change, households closer to a water source were more likely to practice Irrigation and Water Harvesting (IWH) to respond to the water scarcity. The result further indicates that households far from a water source were more likely to participate in water catchment protection than households closer to the water source. A possible explanation is that households far away from water sources are more vulnerable to water scarcity and more affected than households closer to water sources and hence more willing to protect water sources by maintaining trees, shrubs and ground covers around the water sources. Households closer to the produce market were more likely to invest in SWC and protection of water catchment. Better access to the market reduces market related transaction costs and therefore provides an incentive for farmers to undertake adaptive measures since they are assured of higher returns for their produce. Nyangena (2007) had similar findings where closeness to the market increased the use of SWC technologies. In contrast, distance to produce market a positive and significant effect on IWH.

Distance to nearest tarmac road was also used as an alternative indicator to market access. The result indicates that distance to nearest tarmac road negatively and significantly influenced the use of cropping strategy and IWH. This means that households closer to the tarmac road have better access to the market and therefore farmers have an incentive to invest in adaptive water management strategies to respond to changing climatic conditions. Group membership influenced IWH and also protection of water catchment. The results also shows that membership to a group increases the likelihood of farmers to participate in protection of water catchment. This finding is probably due to the benefits farmers can get from groups such as sharing of information (Wambugu *et al*., 2009) Water catchment protection as an adaptive strategy is also best done using collective action than as individual since its benefits might not be excludable. However the results show a negative relation between group membership and use of IWH as an adaptive strategy. This is probable because IWH methods that were practised in the study area were mainly in small scale, and by individual households rather than in groups.

Access to extension services significantly increased the probability of using cropping strategy as an adaptive strategy. Moreover, access to climate information through agricultural extension officers also had a significant and positive influence on SWC. With access to extension services, farmers can get information on changing climatic conditions, production practices and innovations that can be used in adapting to the effects of climate change on water resources. Nhemachena & Hassan (2007) also noted that free extension service increases the probability of adapting to climate change since it was a source of information about climate change, agricultural production and management practices.

Farmers' perception on climatic events positively influenced the use of adaptive water management strategies. For instance, farmers' perception of 'increased flooding' positively influenced protection of water catchment while perception that climate change has led to 'delayed onset rain' increased the probability of using cropping strategy and protection of water catchment.

Similarly, perception that climate change led to ‘decreased rainfall’ increased the likelihood of using irrigation and water harvesting as an adaptive strategy. Lastly, farmers who perceived that climate change has caused degradation of water resources such as rivers and streams were more likely to use SWC as well as protection of water catchment as adaptive water management strategy. Perception of climate change plays an important role in determining whether a farmer will adjust to the effects of climate change. Raising awareness about the climate change effects on water resources at the farm level among the farmers has significant implications on the adoption of adaptive water management. This can enhance the adoption and consequently reduce vulnerability of farmers to climate change risks.

CHAPTER 5 : SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

Reduced availability of water resources at farm-level is a major constraint that is affecting farmers in sub Saharan Africa. Water resources are under threat from rapidly increasing population, water pollution and destruction of water catchment areas. This has been exacerbated by the adverse effects of climate change on rainwater, surface water and ground water resources. Consequently, agricultural production is affected, given that productivity is primarily dependent on water resources. In Kenya, efforts have been made by the government to adapt to climate change effects in agriculture and water resources. Policies and strategies and such as Water Act 2002 and National Climate Change Response Strategy exists to reduce the effect of climate change in agricultural production.

Despite the progress in terms of policies and strategies, more effort is required to reduce vulnerability on climate change effects on water resources at farm level. Better understanding farmers' perception to climate change and adaptive water management is necessary for successful adaptation of climate change based on water resource. The study therefore examined farmers' perception of climate change effects on water resources at farm-level, and the adaptive water management strategies undertaken by crop farmers to respond to the adverse effects of climate change .The study also characterised the adaptive water management strategies practised by farmers in Kakamega County.

Multistage sampling technique was used in the study, Simple Radom Sampling was used to select locations in the Sub County were four locations were randomly selected namely, Mautuma, Chekalini, Lugari and Chevaywa and Systematic random sampling was used to select households where every fourth household was selected from either side of the road in the villages. The study used primary data collected using semi structured questionnaires collected by trained enumerators. A pre survey, four focus group discussions and pretesting of the questionnaire were also conducted to help make necessary adjustments of the questionnaire.

Farmers' level of perception to climate change based on water resources was measured in terms of a five point likert scale. The likert scale was as follows 1=Strongly disagree, 2=Disagree, 3=Somewhat agree, 4=Agree, and 5=Strongly agree. In the first objective, ordered probit model was used to assess factors that influence the levels of perceptions to climate change effects on water resources at farm level. Ordered probit was appropriate since the dependent variable were ordered and discrete in nature. The study found that factors influencing the perception levels to climate change based on water resources were gender, farm size, and distance to the main source of water, contact with an extension officer, wealth status and access to climate change information through radio.

To address objective two of the study, adaptive water management strategies practiced by farmers were characterised. The results indicated that crop farmers in Lugari Sub County are autonomously adapting to the climate change effects on water resources. The main adaptive water management strategies were cropping strategy, irrigation and water harvesting, soil and water conservation techniques, and protection of water resources. In cropping strategy most farmers planted either drought tolerant maize variety or other drought tolerant crops such as sorghum, to adapt to increased cases of water scarcity. Some farmers also planted flood tolerant maize variety to respond to increased cases of intense rains received.

For irrigation and water harvesting (IWH) techniques, some farmers started irrigation while others who had already started irrigation, shifted to improved irrigation methods such as drip irrigation which they considered as water efficient methods. Water storage, rainwater harvesting, runoff water harvesting and digging wells were also practised to enhance availability of water for agricultural use during dry season. Several SWC techniques used by farmers were also identified. They include; mulching (40 percent), planting of covers crops (37.7 percent), digging drainage trenches (37 percent) and planting of trees to reduce soil erosion (42.1 percent). Construction of bunds and ridges and use of stone line (8.2 percent).Some farmers (18 percent) used protection of water catchment as an adaptive water catchment.

To address objective three, multivariate probit was estimated.to assess factors affecting adaptive water management. Cropping strategy, IWH, SWC and protection of water catchment were the main adaptive water management strategies in the study area. The results indicates that there was indeed correlation between adaptive water management strategies among farmers were simultaneous and interdependent. The study found that socio economic characteristics such as age, farm size, farming experience, distance to water source, distance to the produce market, distance to nearest tarmac road, membership to a group, access to extension and access to climate information influenced adaptive water management strategies. Farmers' perception of increased flooding, delayed onset rain, water resources degradation and decreased rainfall received also affected adaptive water management strategy.

5.2 Conclusion

- Understanding climate change perceptions among crop farmers is important in adapting to the effects of climate change on water resources at farm-level. Farmers' perception to climate change corresponds to recorded climate data. Perception of climate risks therefore can play a key role in influencing adaptation policy. The study highlights farmers' differences in climate change perceptions based on water resources at farm level. The levels of perceptions differ depending on household's socio-economics characteristics. The level of perception is determined by how vulnerable the farmer is to the climate change risk or awareness of the climate change risk. In the case of vulnerability, farm size, distance to the nearest water source and wealth status affects the how the farmer perceives climate risks. On the other hand, the level of awareness factors included access to extension services, access to climate information through radio and gender of household head also affects farmer's level of perception.

- National government, county government or NGOs should partner with crop farmers to promote adaptive water management strategies to farmers to adapt to climate change. At the same time, stakeholders can facilitate establishment of pro-poor microfinance to enable farmers to have access agricultural credit resources in order to enhance adoption of adaptive technologies. Increased market access can promote adaptive water management strategies, similarly increased access to both production and climatic information through extension services are also critical in farmers' adaptive decisions with regard to water resources at farm level.

- Availability of better climate and agricultural information helps farmers make decisions on available adaptive water management options that make them respond to climate change by increasing their adaptive capacity. Local organizations such as farmer groups also have a significant role in protection of water catchment as an adaptive strategy. The study reveals that perceptions of climate change risks on farm-level water resources influence the adaptive water management strategy. Therefore, provision of free extension services to farmers has a potential to increase farmers awareness of climate change.

5.3 Recommendation and Policy Implications

From results of the study, possible policy interventions can be suggested. Key conclusions and policy implications from the study are as follows:

1. Since access to climate change information through extension officers or through radio enhances farmer's perception to climate change, more effort should be put to come up with programmes that could help to disseminate climate change information to the farmers. The Kenya government should invest in extension staff to enable farmers to easily access the extension services. Since gender of the household head, farm size and distance to the main source water are found to influence perception of climate change based on water resources, this factors should be considered while designing the policies on climate change. Programmes and policies on climate change should not only be tailored towards the smallholder farmers, but also designed in a way they can achieve gender equity.

2. Since attempts by farmers to adopt technologies such as; drought tolerant variety, flood tolerant variety, water harvesting technologies and soil water conservation techniques have been made, the national and county government as well as non-governmental organizations should invest and facilitate dissemination of technologies that will assist farmers to adopt to the appropriate adaptive water management methods.

3. Proxies for market access (distance to produce market, distance to tarmac road) positively influenced adaptive water management among the farmers. Policies that help farmers to easily access market should be designed to enhance easy access to important inputs to adopt necessary for adoption of new adaptive technologies.
4. Since group membership was found to be significant in enhancing farmers' participation in protection of water catchment as an adaptive water management strategy, collective

adaptation by farmers around the catchment area was critical and has policy implication. Thus, interventions that encourage formation and strengthening of local organizations such as farmer groups should be promoted to encourage protection of water catchment.

5. Age, gender and farm size were also important factors that should be considered in the design of climate change policies to help more farmers undertake adaptive water management. Therefore gender mainstreaming should be encouraged in all climate change programmes in agriculture and water management. The Kenya government should promote irrigation and water harvesting technologies that are suitable to smallholder farmers such as low-cost gravity drip irrigation system, given that farm size influence the adoption of irrigation and water harvesting techniques.

5.4 Suggestion for Further Research

1. This study focused on perceptions and adaptation of climate change based on farm-level water resources where determinants of adaptive water management strategies among farmers were assessed. There is need for further research to focus on profitability of adaptive water management strategies.
2. There is also a need to assess the impact of the adaptive water management strategies on farmer's vulnerability to climate change. Such findings may identify the best adaptive practices for the farmers to respond to the effect of climate change on water resources.

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APPENDIX I: Variance Inflation Factors

VARIABLE	VIF	1/VIF
WEALTH INDEX	1.610	0.621
TOTAL LAND	1.430	0.700
EDUCATION	1.370	0.729
AGE	1.300	0.768
GENDER	1.240	0.809
TARMAC ROAD	1.210	0.827
MAIN OCCUPATION	1.210	0.830
RADIO	1.120	0.893
EXTENSION	1.120	0.895
HH_SIZE	1.110	0.899
WATER DISTANCE	1.100	0.913
OWN EXPERIENCE	1.080	0.926
PRODUCE MARKET	1.080	0.927
MEAN VIF	1.230	

APPENDIX II: Link Test

PERCEPTION	Coefficient.	Std. Error.	z	P>z
_hat	0.603	0.751	0.800	0.422
_hatsq	0.117	0.215	0.540	0.588
n = 159 Prob > χ^2 = 0.0000 Pseudo R2 = 0.1226				

APENDIX III: Ordered probit results

Table 4.2: Ordered probit results for determinants of crop farmers' perception of climate change effects on water resource at farm-level in Kakamega County.

PERCEPTION	Coefficient.	Robust Std. Error	P>z
AGE	0.008	0.008	0.325
GENDER	0.652**	0.268	0.015
HH_SIZE	-0.061	0.043	0.159
EDUCATION	0.018	0.024	0.453
MAIN OCCUPATION	0.260	0.217	0.231
FARM SIZE	0.025**	0.011	0.024
WATER DISTANCE	-0.398***	0.117	0.001
TARMAC ROAD	0.018	0.022	0.408
PRODUCE MARKET	0.149	0.132	0.259
EXTENSION	0.342*	0.193	0.076
OWN EXPERIENCE	-0.267	0.532	0.616
RADIO	0.620***	0.224	0.006
WEALTH INDEX	0.155***	0.043	0.000

n = 159

Statistical significance levels: ***1%, **5% and *10%.

Pseudo R^2 = 0.1216

Prob > χ^2 = 0.0006

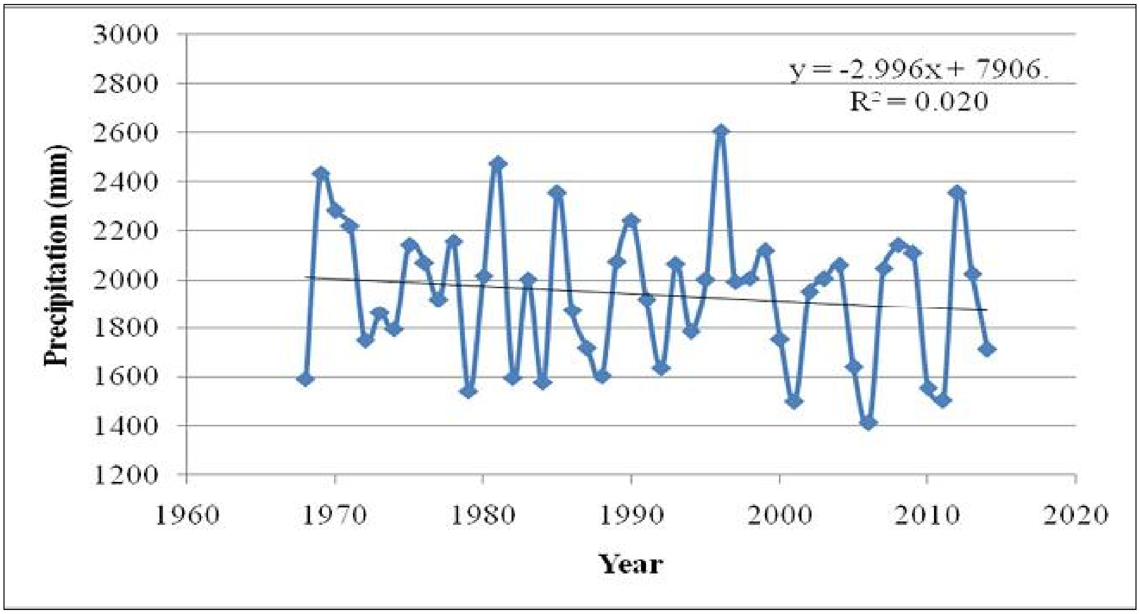
Source: Author's survey (2014)

APPENDIX IV: Likelihood ratio test

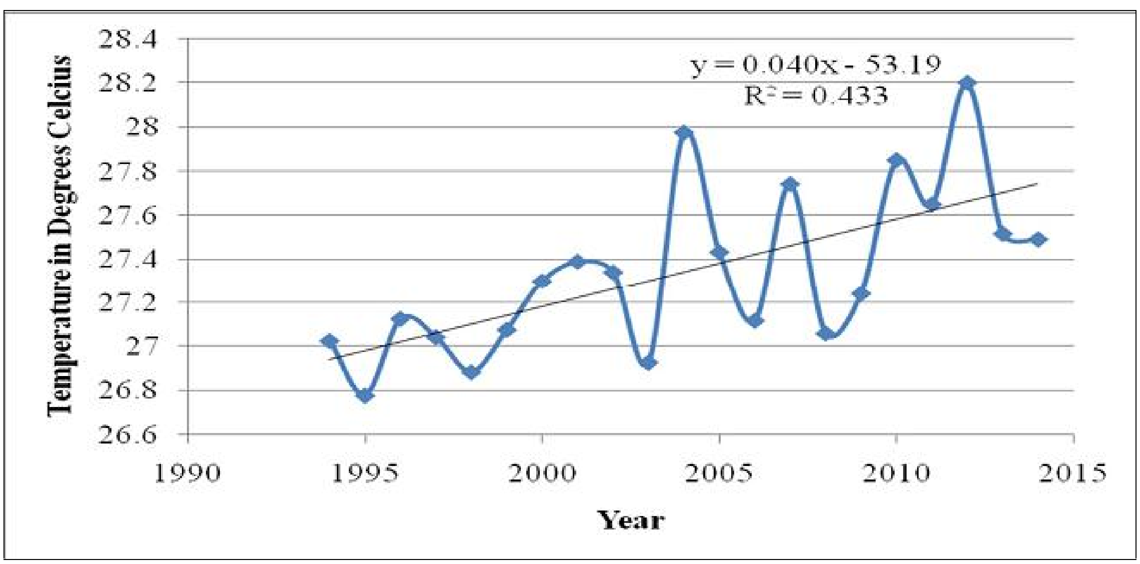
Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0 χ^2 (6) = 37.2891

Where rho is the correlation coefficient between the error terms of the probit equations. The t-test is used to establish if correlation coefficient is significantly different from zero

APPENDIX V: Precipitation trend in Kenya from 1968 to 2014



APPENDIX VI: Temperature trends in Kenya from 1994 to 2014



APENDIX VII: QUESTIONNAIRE

DEPARTMENT OF AGRICULTURAL ECONOMICS, UNIVERSITY OF NAIROBI

QUESTIONNAIRE ON CLIMATE CHANGE PERCEPTIONS AND WATER MANAGEMENT ADAPTIVE STRATEGIES AMONG CROP FARMERS IN KAKAMEGA COUNTY KENYA

INTRODUCTION

University of Nairobi is carrying out a survey which will be used for academic purposes only. Your contribution is voluntary and information you give will be treated confidentially the interview will not more than one hour. The most knowledgeable household member on crop farming will be preferred to respond to the questions.

QUESTIONNAIRE IDENTIFICATION

Enumerator's code ______Date of the interview________________ Start time_________________

County_____________ District_______________ Location ___________ Sub location___________________ Village ______________

Name of the respondent____Mobile Number_______________________

Relationship of respondent to the household head _____________ [*1=head 2=spouse 3=son/daughter 4=other relative 5=worker 6=other (specify)*]

SECTION A: HOUSEHOLD CHARACTERISTICS

ID	1.Name of household member {Start with household head (HHH)}	2.Age	3.Gender (0=Female, 1=Male)	4.Relationship to current HHH (Code A)	5.Marital status (Code B)	6.Highest level of education completed (Code C)	7.Years of schooling	8.Main occupation (Code D)
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
				CODE A **1.** *Head* **2.** *Spouse* **3.** *Parent* **4.** *Child* **5.** *In laws* **6.** *Grandchild* **7.** *Employee* **8.** *Other………………*	**CODE B** 1.*Single* 2.*Married* 3.*Divorced* 4.*Widowed*	**CODE C** 1. *None* 2. *Adult education* 3. *Primary (KCPE)* 4.*Secondary (KCSE)* 5.*College (certificate)* 6. *College (diploma)* 7. *University (degree)* 8. *University (masters)* 9. *University (PHD)*		**CODE D** 1. *Farmer* 2. *Casual labourer* 3. *Salaried employee* 4. *Businessman* 5.*Student* 6.*Other(specify)*

Other characteristics of household head	***Codes***
9.Other occupation (*If Any*)	1=Farming 2=salaried employee 3= Businessman 4=Casual labourer 5=Other (specify)
10.Years of farming experience as a household head	
11.Type of farming	1=subsistence 2=income generation 3=both 4=other (specify)
12. Who makes main crop farming decisions?	1=HHH,2=spouse,3=Daughter,4=Son,5=Several,6=Other(specify)

SECTION B: FARM CHARACTERISTICS AND FARMING ENTERPRISE

Variable	**Code**
1. What is total land owned (Acres)	1=Owned [ ] 2= Rented [ ] 3 Communal land [ ]
2. How much land is dedicated to crop production? (Acres)	1=Owned [ ] 2= Rented [ ] 3.Communal land [ ]
3. What is the main source of water for domestic use	1=Borehole, 2= well,3=Tank 4=Piped water 5=River6=Others(specify)
4.What is the main source of water for crop production	1=Borehole, 2= well,3=Tank 4=Piped water 5=River6=Others(specify
5. What is the distance to the nearest water source(km)	
6. What is the distance to the main produce market?(km)	
7.What is the distance to the main input market?(km)	
8. What is the distance to the nearest tarmac road?(Km)	
9. The enumerator should describe the topography of the land cultivated	0=flat 1= fairly flat 3 = fairly steep 4 = steep 5 = very steep

8. Crops grown in the cropping seasons of 2013

What are your three most important crops? i.e. crops you grow on your farm which are most important to your household’s livelihood.

Cropping season		**Main crop Grown CODE E**: 1=Maize 2=Beans 3=Millet 4=Sorghum, 5=Sunflower 6=Vegetables 7=Sugarcane 8=Sweet potato 9=Cassava 10= others	**Size of the land where crop was planted *(Acres)***	**Crop system** 1=Monocrop 2=Intercrop	**Planted seed/seedling**				**If not purchased how much would you pay per unit were you to buy**	**Quantity harvested**			**What is the market price for this crop?**	
Long Rain	**Short Rain**				**qty**	**Unit**	**Unit Cost *(Kes)***	**Total Cost *(Kes)***		**Amount consumed**	**Amount Sold**	**Unit**	**Price *(Kes)***	**Total**

9. What inputs excluding seed/seedlings did you use during your last cropping year?

Cropping season		Crop system	Type of input and quantity					If not purchased how much would you pay per unit were you to buy	Where did you acquire the input *(Code H)* **1**=Shop/Stockists **2**=Government **3**=NGO **4**=Relative/Friend **5**= Farmer Group **6**=Own **7** Others (specify)	Mode of acquisition 1= cash 2=credit 3=Donation 4=In kind
Season 1	Season 2		Input type *(Code F)* **1**=DAP **2**= UREA **3**= CAN **4**= NPK **5**= Manure **6**=Compost **7**=MAP **8**=Foliar feed **9**=Insecticide **10**=Herbicide **11**=.Fungicide	Quantity	Unit *(Codes G)* **1**=90 kg bag **2**=kg **3**=50 kg bag **4**=Litres **5**=Numbers **8**=Tonnes **9**=Debe **10**=W/barrow **11**=Cart **12**=Gorogoro **13**Others(specify)	Unit Cost *(KES)*	If purchased Total Cost *(KES)*			

Other sources of income other than crop farming

Income description	**Amount (kshs)**	**How often**
Off-farm		
Non –farm		
Remittances		

10. Use of labor by the household on the main crops planted during last two cropping seasons of the year 2013

Cropping season	Farm activity (See **Activity codes** below)	**HIRED LABOUR**					**SHARED/FAMILY LABOUR**		No of Days
		Number of people hired	Average hours worked per day	Number of days worked	KES paid per person per day	If by contract Total (KES)	Number of shared/family labour	Average hours worked per day	

Activity codes: 1= first plough, 2= second plough 3= planting, 4 = Top dressing, 5= Weeding, 6= Manure/Fertilizer application, 7= Ridging& furrowing, 8= Mulching, 9 = Harvesting, 10= Nursery for seedling, 11=, Spraying 12= Bagging/Packing,13= slash and burn

Income from milk production

What is the total income from milk per day?					
	Production/day (litres)	Consumption/day (litres)	Quantity sold / day (litres)	Selling price/ litre	Total milk income/day
Morning					
Evening					
Total					
What are Cost of inputs incurred in milk production?					
	Labour for dairy	Feeds	Vet services and medication	Salt	Other specify
Quantity					
Cost					

SECTION C: CLIMATE CHANGE PERCEPTION

1. Have you noticed any changes in climate or weather patterns over the last 10 years? 1. YES [ ] 2. NO [ ]

If yes in question 1, please rank the statements below in terms of agreement and disagreement using a five point Likert scale (Strongly disagree, Disagree, Somewhat Agree, Agree, Strongly agree).

Climate factor	Strongly Disagree [1]	Disagree [2]	Somewhat agree [3]	Agree [4]	Strongly Agree [5]
1.Overall Increase in temperature					
2.Overall Decrease in temperature					
3.High sunshine intensity					
4.Increased incidences for crop wilting					
5.Unusual early rains that are followed by weeks of dryness					
6.Increase in rainfall					
7.Decrease in rainfall amount					
8.Increased incidence flooding					

9.Increased long period of dry season					
10.Delay in onset rain					
11. Crop pest and disease incidences due to too much rainfall					
12. Increase in weed infestation					
13.Decrease in crop yield					
14.Increase in crop yield					
15. Increased incidences of crop failure					
16. Reduced volume in streams/ rivers					

2. Do you agree that water resources at farm level has been affected by climate change

[1] Strongly disagree [2].Disagree [3] Somewhat agree [4] Agree [5] Strongly agree

SECTION D: WATER ADAPTIVE MANAGEMENT STRATEGIES

1. Do the effect of climate change mentioned earlier affect water availability in your crop production? [1] YES [2] NO

2. If water availability has decreased/increased and has affected crop production as well as your livelihood, what are the key strategies taken by your household to cope up in last the 10 years? Rank according to their importance

Adaptive Water Strategies	**Rank** *(1= Not at all important 2= Not important 3= Average 4= Important 5=Very important)*
1.Do Nothing	
2. Changing planting dates	
3.Mulching of crops to reduce water loss	
4. Planting of drought tolerant crop variety	
5. Started irrigating	
6. Introduced improved irrigation (water efficiency)	
7. Water storage in tanks for agricultural use	
8. Rain water harvesting	
9. Water dams/pans for runoff water harvesting	
10. Planting of plant flood tolerant variety	
11. Planting cover crops	
12. Build ridges and bunds	
13. Introduced trenches to increase drainage	
14. Introduced stone lines	

15. Plant trees to reduce soil erosion	
16. Dig bore holes/wells to supply water during dry seasons	
17. Protection of water catchment	
18. Others, specify	

4. If irrigation is one of the main strategy, what is the source of irrigation water? _____________

1= River, 2= Stream, 3= constructed pond/reservoir/pans,4=.Well/borehole, 5=spring

5. What is the type of irrigation? ______________

1= sprinkler, 2= drip 3= furrow, 4= flood

6. What other adaptation strategy has your household adopted other than the water adaptive strategies?

1=Get off farm job, 2=Buy weather index insurance, 3=Changing planting dates, 4= Reduce the farm size, 5=Seeking climate information, 6=Pray to God 7=Other(specify)

SECTION E: INSTITUTIONAL FACTORS

	Variable	**Response**	**codes**
1	Are you a member of a group?		*1=Yes 2=No*
2	What type of Group ***(if yes)***		*1= Self-help group 2 =Women group 3= Saving and Credit Association 4= Church group*
3	What are the activities of group?		*1. Marketing, 2 Merry go round 3 Credit 4 Savings 5 Welfare*
4	Have you had any contact with an extension officer in the last three years?		1 Yes [ ] 2 No [ ]
5	If yes in 4 when was the last contact *(year)*		

ACCESS TO CREDIT

9. Did your household attempt to borrow from any source (cash or in kind) in the last 3 years? 1. Yes [ ] 2. No [ ]

10. If **YES**, what were the characteristics of the credit you accessed?

Type of credit *1.Commercial bank* *2.Micro finance* *3.Cooperative* *4.Trader/Stockist* *5.Money lender* *6.Friend/relative* *7.Merry go around* *8.Other*_________	**Item of credit** *1=Cash* *2=In kind*	**Location** *1=Within* *2=Outsides* *3=Other*	**Amount** *If in kind estimate value(Ksh)*	**Borrowing purpose** *1=school fees* *2=farming activities* *3=building* *4=investment* *5=domestic use*	**Borrowing conditions**

11. If **NOT**, why so? ____

1=No need for loan, 2= Afraid of losing collateral, 3=cannot pay the money back, 4=inadequate collateral, 5=Has outstanding loan, 6= Bad credit history, 7=High Interest rates, 8=Lenders not located nearby, 8= Procedures too cumbersome 9= Family dispute in borrowing 10= No access to lending groups 11.Other, specify

LIVESTOCK INVENTORY

Livestock type	**Ownership**	**Number**	**Value (if you**	**Total value**	**How many did you**	**How many did you**

	(1=yes, 2=no)		were to buy)		sell in the last one year?	consume in the last one year?
1. Grade cows						
2. Local cows						
3. Cross cows						
4. Bulls						
5. Heifer						
6. Calves						
7. Goats						
8. Sheep						
9. Chicken						
10. Donkey						
11. Other Poultry						

HOUSEHOLD ASSETS

Name of the Asset	Ownership (1=Yes, 2=No)	Number
FARM		
Water pump		
Knapsack sprayer		
Ox-plough		
Hoe		
Spade/shovel		
Wheelbarrow		
VEHICLE		
Motorcycles		
Car/Lorry/Pickup/Taxi		
Push cart (Mkokoteni)		
Tractor		
Bicycles		
DOMESTIC		
Solar panel		
Gas cooker		

Electric stove		
Improved charcoal stove (*jiko*)		
Kerosene stove		
COMMUNICATION		
Mobile phone		
Television		
Radio		
OTHERS		

What is the building material of your main house?

	Mud	Iron Sheet	Tiles	Bricks	Wood	Stone	Grass Thatched
Wall							
Roof							
Floor							

12 What are your sources of agricultural and climate change information? Please **RANK** the sources

Information source	**Rank**
Agricultural extension officers	
Television	
Radio	
Farmers' own experience	
Fellow farmers	

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