SMALL-SCALE FARMERS' PERCEPTIONS AND ADAPTATION MEASURES TO CLIMATE CHANGE IN KITUI COUNTY, KENYA

BY

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Declaration

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Abstract

Climate variability and change is affecting weather patterns and seasonal shifts with serious repercussions on rural households. Semi arid environments such as Kitui County, are extremely vulnerable to climate change because their production systems are climate sensitive, and large segment of the population is least able to buffer and rebound from climatic stress. Yet, there is a dearth of information on agricultural adaptation strategies embraced by farmers in this region, or whether farmers are aware of the changing climate and its impacts. To address this gap, my study assessed farmer perceptions, established coping mechanisms and examined factors influencing adaptation uptake. Such information is vital to develop optimal intervention measures that will build resilience and reduce vulnerability. Both primary and secondary data were used in this study. Primary data were collected from interviews with key informants, focus group discussions (FGDs) with farmers, and household questionnaire survey. Using semi-structured questionnaire, 332 farmers were assessed on their perceptions of climate change and how they were adapting to the impacts. The study also analysed maize crop yields in relation to rainfall over a 17 year period. Farmer perceptions were analysed in relation to meteorological data. Determinants of perceptions and adaptations were then examined using Heckman probit model and multivariate biprobit model (MVBP). Regression analysis shows that the mean annual rainfall for the area was decreasing at 34 mm per year ($y = -34.272x + 691.82$). There was a high positive correlation between rainfall and maize yields (R=0.819, p<0.001, n=17). Farmers' perceptions that the region is getting drier were consistent with the rainfall data. The Heckman probit and MVBP models show that extension service, educational attainment, membership to social and economic group, and access to water were the major factors influencing adaptation uptake. Improving these factors will be important to enhance adaptive capacity at the household level. Thus, national and county governments should develop and implement integrated policies and programs that enhance farmer awareness to climate change, build local resilience, and promote transition to climate-smart agriculture.

Keywords: adaptation, climate change and variability, perception, vulnerability, agriculture, Kitui County

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Abbreviations and Acronyms

AEZ	Agro-Ecological Zones
AIDS	Acquired Immune Deficiency Syndrome
ASALs	Arid and Semi-Arid Lands
CBOs	Community Based Organisations
FAO	Food and Agricultural Organisation
GDP	Gross Domestic Product
GHG	Greenhouse Gases
HIV	Human Immunodeficiency Virus
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
ICPAC	IGAD Climate Prediction and Applications Centre
IFAD	International Food and Agricultural Development
IPCC	Inter-governmental Panel on Climate Change
LSD	Least Significance Difference
MVBP	Multivariate biprobit
MNL	Multinomial logit
NDMA	National Drought Management Authority
NEMA	National Environment Management Authority
NGO	Non-Governmental Organisation
ODI	Overseas Development Institute
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

CHAPTER 1: INTRODUCTION

1.1 Background to the Study

There is a consensus that over the coming decades, anthropogenic climate change will cause dramatic transformations in the biophysical systems that will affect human settlements, ecosystem services, water resources and food production; all of which are closely linked to human livelihoods (UNFCCC, 2005; IPCC, 2001, 2007; O'Brien & Leichenko, 2007; Mearns & Norton, 2010). These transformations are likely to have widespread implications for individuals, communities, regions and nations. In particular, poor, natural resource-dependent rural households will bear a disproportionate burden of the adverse impacts (Adger, 2001, 2003; Burton, Diringer & Smith 2006). The extent to which these impacts will be felt depends in large part on the extent of local and national adaptations and adaptive capacities (Shah, Fischer &Velthuizen, 2008; Yesuf *et al.,* 2008; Mearns & Norton, 2010).

Although there is a considerable scientific uncertainty about the future trajectory of climate change, its impacts are already discernible and will increasingly affect the basic elements of life for people around the world (IPCC, 2007). Such impacts include those on numerous agricultural regimes, and human health including infectious disease vectors (Adger *et al*., 2007). Africa is at the tip of the spear of climate change impacts mainly due to the interactions of multiple stressors, including extreme poverty, over-dependence on rain-fed agriculture, HIV/AIDS prevalence, insufficient public spending on rural infrastructure, poor data availability and quality, and knowledge gaps (UNEP, 2005; IPCC, 2007). These stressors contribute to a weak overall adaptive capacity, and thus may compound poverty for vulnerable groups.

While climate change is a global phenomenon, potential effects are not expected to be uniform; rather they are unevenly distributed, both between and within countries (Hunter, Salzman & Zaelke, 1998; O'Brien & Leichenko, 2008). Moreover, the differential impacts on the livelihoods of human population vary and are largely determined by the location of settlement, and levels of income, education and awareness (Hunter *et al.,* 1998). Thus, vulnerability to climate change is a function not just of geography and dependence on natural resources, but also of socio-political and institutional factors which influence how climate change ramifications unfold (Adger, 2006). The most vulnerable are often the poor, politically disenfranchised and marginalised communities, who are among the first to experience the impacts and least equipped to diversify their livelihoods (Eriksen *et al.*, 2008; Mannke, 2011). As a result, low income populations dependent on subsistence farming will increasingly face severe hardships because they have little flexibility to buffer potentially large shifts in their production bases (FAO, 2008; Ribot, 2010). Climate stresses will push these populations over an all-too-low threshold into an insecurity and poverty that violates their basic human rights (Moser & Norton, 2001).

Adaptation to climate change and variability is widely acknowledged as a vital component of any policy response. Studies show that low input farming systems, such as subsistence agriculture in marginal areas is not only unsustainably depleting the natural resource base; it is also demonstrably ineffective at alleviating rural poverty (IPPC, 2007; Milder, Majanen & Scherr, 2011). Thus, without adaptation, climate change will push poor rural farmers on a razor's edge of survival, but with adaptation, vulnerability can largely be reduced (Adams *et al.*, 1998; FAO, 2008).

Adaptation to climate change involves a two-stage process: first perceiving change and then deciding whether or not to adapt (Maddison, 2006). Perception is therefore, a precondition for adaptation. Agricultural adaptations embrace a wide range of options that include: micro-level options, (e.g. crop diversification and altering the timing of operations); market responses, (e.g. income diversification and credit schemes); adaptive capacity and institutional strengthening, (e.g. developing meteorological forecasting capability, improvement in agricultural markets and information provision); and technological developments, (e.g. development and promotion of new crop varieties and integrated water management) (Smit & Olga, 2001; SEI, 2009). Most of these choices represent possible adaptation measures rather than the actual farm level adaptation strategies. Indeed, there is limited evidence that these adaptation options are feasible, realistic, or even likely to occur.

1.2 Statement of the Research Problem

Climate change and variability is affecting weather patterns and seasonal shifts with serious repercussions on poor rural households and communities in Kenya (ROK, 2010). Since agriculture is intimately linked to climate, policy makers have expressed concerns regarding the potential effects of climate change on agricultural production systems.

As a semi-arid region, Kitui County is among the most drought-vulnerable regions in Kenya. The manifestation of climate change has resulted into unpredictable and depressed crop yields and loss of livestock, leading to perennial food shortages and over-reliance on emergency food-based interventions to meet local food deficit (ROK, 2005). While small-scale farmers in Kitui are more diversified across crops, maize is the main rain-fed crop cultivated throughout the County reflecting cultural dependence on it as a staple food.

There is, however, a scarcity of information on agricultural adaptation strategies embraced by the farmers in Kitui region. Thus need to examine explicitly the how, when, why and what conditions adaptation actually occurs in economic and social systems (Smit & Olga, 2001), and implications of future climatic conditions. This is crucial in designing and implementing integrated policies that will enable the small-scale farmers to operate sustainable agricultural production systems. To address this gap, this study was designed to assess farmer perceptions of climate change, establish coping mechanisms, and assess factors influencing the adoption among small-scale households in Kitui County.

1.3 Research Questions

1. Has the climate for Kitui changed and how has that affected staple crop yields?
2. What is the perception of small-scale farmers in Kitui County on climate change and how are they adapting?
3. What factors influence the adoption of these coping mechanisms?

1.4 Study Purpose and Objectives

The study aimed at attributing climate change to poor crop yield, assessing farmer perceptions of such change, their coping mechanisms and factors influencing uptake of these mechanisms.
The specific objectives were:

1. To analyse rainfall patterns and impacts on maize crop yields for Kitui County.
2. To determine farmer perception of climate change and their coping mechanisms and/or adaptation measures.
3. To assess factors influencing perceptions, coping mechanisms and uptake of adaptation measures.

1.5 Justification of the Study

The uncertainty about future trajectory of climate change is posing serious challenges on the nature of change and the accompanying consequences, preventing people at different levels from making critical decisions that are necessary to adapt. While a detailed knowledge of likely or potential future climate would be desirable, lack of it should not be an impediment to increasing the general resilience of societies to future environmental threats. In this regard, the study does not only allow the assessment of outcomes that facilitate policy consideration and decision making in the face of future uncertainty, it also builds the knowledge base to guide adaptation of agricultural systems. This will reduce the vulnerability of rural households and increase the opportunities for sustainable development.

Kitui County was chosen because it is semi-arid area with a large number of small-scale agro-pastoralists. On the other hand, the topic was chosen because agriculture is the leading sector in the Kenya's economy in terms of its contribution to real Gross Domestic Product (GDP). In addition, smallholder agriculture absorbs the largest share of new additions of the labour force.

CHAPTER 2: LITERATURE REVIEW

2.1 Adaptation and Vulnerability to Climate Change

2.1.1 Adaptation to Climate Change

Adaptation to environmental change is a norm rather than exception. Throughout human history, societies have adapted to natural climate and environmental changes by altering settlement and agricultural patterns and other facets of their economies and lifestyles (McCarl *et al.,* 2001; Easterling, Hurd & Smith, 2004; Burton *et al*., 2006; Adger *et al*., 2007; Heltberg, Siegel & Jorgensen, 2008). Thus, most societies are reasonably adaptable to changes in average conditions, particularly if they are gradual (Burton *et al.,* 2006). However, communities are more vulnerable and less adaptable to human-induced climate change.

Adaptation to climate change has become one of the focal points of current development discourse, particularly agriculture. As a result, it has found expression as a response strategy in the UNFCCC and the resulting Kyoto Protocol in 1997. Article 4.1 (f) of the UNFCCC commit parties to:

> *Take climate change considerations into account, to the extent feasible, in their relevant social, economic and environmental policies and actions, ..., with a view to minimizing adverse effects on the economy, ..., to mitigate or adapt to climate change.*

The rise of climate change adaptations to political currency is two-fold: developing countries are extremely vulnerable to climate change impacts, because a large proportion of their economies is climate sensitive, and they have less adaptive capacity (IPCC, 2007).

This thesis is premised on the concept of adaptation of people and their livelihoods to climate change. Adaptations are adjustments in ecological-social-economic systems in response to actual or expected climatic stimuli, their effects or impacts (IPCC, 2001; Smit & Olga, 2001). Thus, adaptation can reduce adverse impacts of climate on human health and well-being, and increase the capacity to take advantage of the opportunities (IPCC, 2007; Smit & Olga, 2001). Regarding human dimensions, adaptation to climate change entails adjustments in socio-economic arrangements that reduce the vulnerability of households, communities, groups, sectors, regions, or countries to changes in the climate system (Smith, 1997; Smit & Wandel, 2006; Fussel, 2007).

The goal of climate change adaptation is to build the resilience of communities towards different kinds of changes in their environment. Resilience is the capacity to maintain competent functioning in the face of major life stressors (Adger, 2000). Thus, it demonstrates the capacity of human systems or entities to bend without breaking in the face of disturbance and, once bent, to spring back to its pre-disturbance steady state (Easterling et *al*., 2004). Unlike natural ecosystems, human systems have the capacity of foreseeing and adapting to possible environmental changes (Adger, 2000; Folke *et al.,* 2002; Easterling *et al*., 2004). When a social or ecological entity loses resilience, it becomes more vulnerable to changes that previously could be absorbed and adapted to (Folke *et al*., 2002). Sustainability of humans on earth is linked to resilient socio-ecological systems, which is influenced by human capital and institutional arrangements (O'Brien *et al*., 2012)

The terms "coping" and "adaptation" are often used interchangeably to reflect strategies for adjustments to changing climatic and environmental conditions (O'Brien *et al*., 2012). However, the two are associated with different time scales and represent different processes (Eriksen & Kelly, 2007). Whereas, coping is a short term reactive response to climate variability, adaptation is associated with longer time scales and points at adjustments as fundamental changes of the systems practices, processes or structures to changes in mean conditions (Ibid). With adaptations, new coping range is established (Smit &Wandel, 2006).

Nonetheless, coping strategies may become adaptive strategies when people are forced to use them over a run of bad years and across seasons rather than just at the worst time of the year (Anderson *et al*., 2010). Besides, the way households cope with crises either may enhance or constrain the future coping strategies, as well as their possibilities to adapt in the longer term (O'Brien *et al*., 2012).

Adaptation types have been differentiated according to numerous attributes. Commonly used distinctions are purposefulness and timing (Smit & Olga, 2001). The IPCC (2007) recognises three types of adaptation: First, autonomous, or spontaneous adaptations are considered to be those that take place – invariably in unconscious and reactive response – after initial impacts are manifest to climatic stimuli as a matter of course, without the intervention of public policy. Second, anticipatory, or proactive adaptation takes place before the impacts of climate change are apparent. Third, planned adaptation is based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state. However, due to institutional constraints, planned adaptation has been slow in forthcoming in many developing countries, and populations are most vulnerable to disrupted agricultural production (Maddison, 2006).

Whereas planned adaptations are intervention strategies, autonomous adaptations occur naturally without interventions by public agencies (Smith *et al.,* 1996). Thus defined, autonomous and planned adaptations largely correspond with private and public adaptation, respectively. However, it is the autonomous adaptation that forms a baseline against which the need for planned anticipatory adaptation can be evaluated (Smit & Olga, 2001).

2.1.2 Vulnerability to Climate Change

Vulnerability can be defined from different perspectives, depending on the stakeholders involved (Adger, 2006; Heltberg *et al.,* 2008). Vulnerability to climate change does not exist in isolation from the wider political economy of resource use. It is often driven by inadvertent or deliberate human action that reinforces self-interest and the distribution of power, besides interacting with biophysical systems (Ribot, 2010).

The policy context in which climate risks are dealt with and adapted to is informed by two polarized interpretations of vulnerability, namely, risk-hazard and social constructivist frameworks (Kelly & Adger, 2000; Adger 2006; Füssel & Klein 2006; O'Brien *et al.*, 2007).The risk-hazard model tends to evaluate the multiple outcomes of a single climate event, whereas the social constructivist framework characterizes the multiple causes of single outcomes (Adger, 2006).

The risk-hazard approach sees vulnerability as a linear result of climate change impacts and aims at reducing the projected impacts through technological 'fixes'(Eriksen & Kelly, 2004; Fussel, 2007; O'Brien *et al.,* 2007). On the other hand, the social constructivist framework considers vulnerability as an attribute of social and ecological systems that are generated by multiple factors and processes (Eriksen & Kelly, 2004). Unlike the risk-hazard model that places the burden of explanation of vulnerability within the biophysical system, the social constructivist framework places the same burden within the social system (Adger, 2006; Ribot, 2010).

Although both frameworks of vulnerability are useful for policy response to environmental change, an integrative framework is more useful for planned adaptation to climate change. This is because it links the two approaches and views vulnerability as depending on both biophysical and human factors. Besides, vulnerability is portrayed as having "an external dimension, which is represented by the 'exposure' of a system to climate variations, as well as an internal dimension, which comprises its 'sensitivity and its adaptive capacity" to these stressors' (Füssel & Klein, 2006).

The extent to which natural and socio-economic systems are at risk to anthropogenic climate change depends not only on the degree of exposure, but also on the sensitivity of a system to the impact and its adaptive capacity (Smit & Olga, 2001; IPCC, 2001, 2007). The exposure of a system refers to the degree of a perturbation, stress, hazard or shock, which causes a significant transformation or changes to a system, and can happen suddenly or over a longer period of time (Gallopin, 2006). On the other hand, sensitivity is the degree to which a system is affected or modified by climate change without accounting for adaptation (Easterling *et al.*, 2004. The impacts may be harmful or beneficial as well as direct or indirect (Gallopin, 2006; IPCC, 2007).

The adaptive capacity relates to the system potential or capacity to react to the impacts or transformations related to climate change, moderate potential damages, take advantage of opportunities, or cope with the consequences. It demonstrates the system's ability to accommodate or deal with exposure, and expand a range of options with which it can prepare for and undertake adaptation (Adger, 2006; Gallopin, 2006; IPCC, 2007; O'Brien *et al.*, 2012).

The adaptive capacity of households and communities is determined by their socio-economic characteristics such as access to financial, technological and information resources, the institutional architecture within which adaptations occur, human capital, political influence, and kinship networks (Easterling *et al.*, 2004; Smit & Wandel, 2006; Heltberg *et al.*, 2008).

2.2 Impacts of climate change on agricultural production

The projections of future climate change are uncertain especially in relation to scenarios of future rainfall, floods and droughts. However, temperature projections are generally more reliable. A warming throughout sub-Saharan Africa is projected to be larger than the global annual average (IPCC, 2007). As regards rainfall, some model predictions indicate that East Africa region is going to have increased rainfall events (IPCC, 2007; SEI, 2009; Seitz & Nyangena, 2009), while other recent research suggests that local circulation will result in depressed precipitation instead (Funk *et al*, 2008). Nonetheless, the climate is changing already and a striking consensus is that the future climate is unlikely to be the same as at present. Thus there is need to apply precautionary principle on the grounds that the costs of not acting are likely to be incalculably high.

Spatial and temporal variation of precipitation and increased temperatures are the main climate change related drivers, which impact agricultural production (ODI, 2009). Increased temperature levels will cause additional soil moisture deficits, crop damage and crop diseases; unpredictable and more intense rainfall; and higher frequency and severity of extreme climatic events (Boruru, Ogara & Oguge, 2011). Similarly, the drivers of climate change have the potential of altering plant growth and harvestable yield through carbon dioxide fertilization effects (UNDP 2012). Free Air Carbon Enrichment (FACE) experiments indicate productivity increases in a range of 15 – 25% for C_3 crops (wheat, rice and soya beans) and 5 – 10% for C_4 crops (maize, sorghum and sugarcane). Higher levels of carbon dioxide also improve water use efficiency of both C_3 and C_4 plants (Lotze-Campen & Schellnhuber, 2009). However, there is uncertainty about the magnitude of the positive effects of enhanced carbon dioxide concentration.

Climate change will interlock with people's life-worlds differently for different reasons. The geography of a people's location relative to other people may position them more acutely in harm's way when climate change ramifications unfold (Boruru *et al.*, 2011). In mid to high latitude regions, moderate local increases in temperature can have small beneficial impacts on crop yields, while in low latitude regions, such moderate temperature increases are likely to have negative yield effects (Iglesias, 2006; Aydinalp & Cresser, 2008; IAASTD, 2009). This will significantly increase yield variability in many regions of the world, and result into polarization of effects with substantial increases in prices and risk of hunger amongst poorer nations (Iglesias, 2006; UNDP, 2012). However, through advance preparation and careful management of agricultural systems, these risks could be substantially reduced. Recent studies show that for each 1°C rise in average temperature, dryland farm profits in Africa will drop by nearly 10% (FAO, 2008). Similarly, yields from rain-fed crops could be halved by 2020, and net revenue from crops could fall by 90% by 2100 in some countries in Africa (UNFCCC, 2007).

Extreme climatic events of drought and floods are threat to agricultural system and could bring about both chronic and transitory food insecurity. This is because many crops have annual cycles and yields that fluctuate with climate variability, particularly rainfall and temperature (FAO, 2008). As a consequence of climate change, rural areas that depend on rain fed agriculture will become more vulnerable to food insecurity.

2.3 Agricultural Adaptation

2.3.1 Introduction

Agricultural adaptation is a vital policy response that will shape the future severity of climate change impacts on food security. Studies indicate that adaptation can lessen the yield losses that might result from climate change, or improve yields where climate change is beneficial (Adams *et al.,* 1998). Although relatively inexpensive adaptation options such as crop diversification and altering the timing of operations, may moderate adverse impacts, the biggest benefits will likely result from more costly measures including institutional strengthening and technological developments (Easterling *et al.*, 2004; Smit & Wandel, 2006). These adaptation measures, alongside other competing interests, will require substantial resource allocation by farmers, national and county governments, scientists and development partners.

2.3.2 Levels of Agricultural Adaptation

Adaptation occurs at two main levels: the farm-level and macro-level (Kandlinkar & Risbey, 2000). While the farm level is focused on micro analysis of farmer decision making, the macro level deals with national agricultural production and its relationships with domestic and international policy (Ibid). Farm-level decisions are short-term and made in response to seasonal climatic shifts, and therefore, determined by socioeconomic variables such as household characteristics, household resource endowments, access to information and availability of formal institutions. Contrastingly, macro-level analysis is long-term strategic national decisions and policies made in response to long-term changes in climatic and market conditions.

2.3.3 Determinants of Adoption

The literature on adoption identifies a range of household and farm characteristics, institutional factors, and local climatic and agro-ecological conditions as the key the determinants of the speed of adoption (Maddison, 2006; Gbetibouo, 2009). The adaptation options taken by most farmers are not only those that build adaptive capacity and enhance climate resilience, but also those that will address conservation of natural and environmental resources (SEI, 2009).

The household characteristics which have significant impact on adoption decisions include age, education level, gender of the head of the household, family size, years of farming experience, and wealth. The age of a farmer may positively or negatively influence the decision to adopt new technologies (Gbegeh & Akubuilo, 2012). Older farmers have more experience in farming and are better able to assess the characteristics of modern technology than younger farmers, and hence a higher probability of adopting the practice. On the other hand, older farmers are more risk-averse and less likely to be flexible than younger farmers and thus have a lesser likelihood of adopting new technologies (Adesina & Forson, 1995). Younger farmers are likely to incur lower switching costs in implementing new farming practices since they have limited experience and therefore, adjustment costs involved in adopting new technologies may be lower for them (Marenya & Barrett, 2007).

Education and human capital endowments are often assumed to increase the likelihood of embracing new technologies. This is because they enhance the ability of farmers to perceive climate change (Nkonya *et al.,* 2008). Similarly, education enables households to access and conceptualize information relevant to making innovative decisions (Adesina & Forson 1995; Daberkow & McBride 2003; Shiferaw, Okello & Reddy, 2009; Ochieng', Owuor & Bebe, 2012, Gbegeh & Akubuilo, 2012). However, higher educational attainment can present a constraint to adoption because it offers alternative livelihood strategies, which may compete with agricultural production.

The effect of gender of the household head on adoption decisions is location-specific (Gbetibouo, 2009). In many parts of Africa, women are often deprived of property rights due to social barriers (Gbegeh & Akubuilo, 2012). Consequently, they have fewer capabilities and resources than men (Quisumbing *et al*., 1995; De Groote & Coulibaly, 1998; Marenya & Barrett, 2002; OECD, 2009; Gbegeh & Akubuilo, 2012). This often undermines their capacity to embrace labour-intensive agricultural innovations. However, female-headed households are more likely to take up climate change adaptation measures (Nhemachena & Hassan, 2007; Gbetibouo, 2009). The possible reason for this observation is that in most rural smallholder farming communities in Africa, more women than men live in rural areas where much of the agricultural work is done. In this respect, women have more farming experience and information on various management practices and how to change them, based on available information on climatic conditions and other factors such as markets and food needs of the households (Nhemachena & Hassan, 2007).

Asset endowments and wealth have a significant influence on the ability of smallholder farmers to adopt certain technological practices (Reardon & Vosti, 1995; Nkonya *et al.*, 2008; Gbetibouo, 2009). Households with higher income and greater assets are less risk averse than lower income households, and therefore in better position to adopt new farming technologies (Shiferaw & Holden, 1998).

The influence of household size on the decision to adapt is uncertain. Household size as a proxy to labour availability may influence the adoption of a new technology positively as its availability reduces the labour constraints (Marenya & Barrett, 2007; Teklewold *et al.*, 2006). Given that the bulk of labour for most farm operations in sub-Saharan Africa is provided by the family rather than hired, lack of adequate family labour accompanied by inability to hire labour can seriously constrain adoption practices (Nkonya *et al.*, 2008). Nonetheless, households with many family members may be forced to divert part of the labour force to off-farm activities in an attempt to earn income to ease the consumption burden imposed by a large family size (Tizale, 2007; Gbetibouo, 2009).

The farm characteristics that could influence the adoption decisions include farm size and soil fertility. Farm size influences both the access to information and the adoption decisions. More crop acreage is likely to enhance the information exposure to site-specific crop management technologies because these technologies would likely be marketed to larger farms (Marenya & Barrett, 2007; Daberkow & McBride, 2003). Given the uncertainty and the fixed transaction and information costs associated with innovation, there may be a critical lower limit on farm size that prevents smaller farms from adapting (Daberkow & McBride, 2003; Gbetibouo, 2009; Gbegeh & Akubuilo, 2012). Thus, large mechanised farms will probably be the first to adapt to climate change.

Institutional factors that influence adoption of new technologies includes access to credit, information provision, off-farm employment, and land tenure. Institutional strengthening via access to formal and informal institutions and meteorological capability increases the likelihood of uptake of adaptation techniques. Households with access to formal agricultural extension, farmer - to - farmer extension and information about future climate change are more likely to adjust their farming practices in response to climate change (Smit *et al.*, 2001; Mariara & Karanja 2007; Yesuf *et al.*, 2008; Nkonya *et al.*, 2008). In addition, farmers with access to extension services are likely to perceive changes in the climate because they have information about climate and weather changes (Gbetibouo, 2009). However, certain information sources can be more effective "change agents" than others and various information sources can influence the probability of adoption differently (McBride & Daberkow, 2003). Similarly, different sources of information become influential during different stages of adoption process. The mass media for instance, are important in the early awareness stage, while interpersonal information sources such as extension officers and other farmers are critical in transferring more technical and adoption-promoting information (Ibid). Although technical information from extension services is shown to be most important to the potential adopter, the extension-farmer linkages are extremely weak in some parts of Sub-Saharan Africa and most agricultural information is obtained via farmer-farmer contacts (Adesina & Forson, 1995). This suggests that farmers are also important as sources of technology information and agents of technology transfer. Studies also reveal that adoption technologies flow through social networks, and do not necessarily spread because of geographical proximity (Maddison, 2006). Thus future extension should engage farmer cooperatives in research process and on-farm trials for a variety of evaluation and demonstrations. The trained farmers will then be able diffuse the adoption technologies since heterogeneity of farm situation invariably makes it difficult to provide government extension (Pannell, 1999)

Studies have shown that under conditions of imperfect credit, smallholder farmers and resource users will adopt certain conservation practices (Reardon & Vosti 1995; Gbetibouo, 2009).This is because the adoption of new technologies requires borrowed or owned capital. Thus lack of borrowing capacity may hamper any efforts to embrace adaptation measures that require heavy investment upfront such as irrigation, terracing, tree planting and fertilizer use.

The other institutional factor conditioning the adoption of adaptation technologies mainly relate to the prevailing system of property rights (Gbetibouo, 2009; Shiferaw, Okello & Reddy, 2009). Tenure security can contribute to adoption of technologies linked to land such as irrigation equipment or soil conservation practices. Farmers lack economic incentives to invest their time or money if they cannot capture the full benefits of their investments (Ibid). This condition may prevail when they have insecure rights to land or when the natural resource is governed by open access property regime.

2.4 Climate-Smart Agriculture

The nexus between agriculture and climate change is real and potentially deadly. On one hand, the agricultural value chain, and land use change, including deforestation account for 30% of the total global GHG emissions; while on the other hand, the adverse impacts of climate change are leading to land degradation, and food insecurity (IPCC, 2007; Celso *et al.,* 2012). And yet, agriculture has the potential to be part of the solution through integrated approaches of food security, adaptation and mitigation (World Bank, 2011, 2012).

In Low Income Countries, agriculture accounts for most land use, and thus the single most influence on environmental quality. Similarly, agriculture remains the principal livelihood of the rural poor. Yet patterns of rural population growth and agricultural expansion and intensification pose serious challenges to achieving both environmental improvements and rural poverty reduction (Scherr, 2000).

Livelihood security requires more resilient production systems. Similarly, more productive and resilient agriculture requires management of natural and environmental resources (FAO, 2010). Transiting to such systems could generate significant mitigation benefits (FAO, 2010; World Bank, 2011). Climate-smart agriculture seeks to increase productivity in an environmentally and socially sustainable way, to strengthen farmers' resilience to climate change, and to reduce agriculture's contribution to climate change by reducing greenhouse gas emissions and increasing soil carbon sequestration (FAO, 2010; World Bank, 2011).

Climate-smart measures includes proven techniques – such as mulching, intercropping, integrated pest and disease management, conservation agriculture, crop rotation, agro forestry, integrated crop-livestock management, aquaculture, improved water management, better weather forecasting for farmers – and innovative practices, such as early warning systems (FAO, 2010; World Bank, 2011; 2012). It also entails embracing new technologies – such as diversifying genetic traits of crops to help farmers edge against an uncertain climate – and creating an enabling policy environment for adaptation (World Bank, 2011). In the absence of climate-smart agriculture, marginal areas may become less suited for arable farming as a result of land degradation through deforestation, soil erosion, repetitive tillage and overgrazing (World Bank, 2012).

Climate-smart agriculture is location-and production system-specific. Thus, its precise nature is influenced by local factors including the climate, types of crops grown and livestock reared, available technologies and knowledge and skills of individual farmers (FAO, 2010). However, there is recognition that climate-smart efforts must have at their heart smallholder farmer who is key to change across the entire agricultural system. Thus, policy-makers have continued to explore carbon finance as a lever to promote sustainable agricultural practices that have many other direct benefits for smallholder farmers and the environment.

Yet, a number of serious concerns remain unaddressed. Soil carbon sequestration prescribes a package of "best" management practices that score highest on sequestration rates. This might undermine farmers' dynamic and diverse adaptation strategies (Celso *et al.*, 2012). Second, the expansion of soil carbon markets encourages private actors to extend their control over land without taking into account local land tenure arrangements, and often at the expense of smallholder and marginal farmers who do not have equal negotiating power compared to large landowners (Ibid)

Third, climate-smart agriculture is premised on a non-existent soil carbon markets (FAO, 2008). The major loophole in the packaging of carbon trading within climate-smart agriculture is the scientific uncertainties about the quantification and verification of soil carbon (Celso *et al.*, 2012).

2.5 Gaps in Literature Review

A substantial body of literature addresses possible impacts of climate change on agriculture. Most of these observations indicate that farmers can overcome the adverse impact of climate change by implementing adaptation measures (Adams *et al.*, 1998; Yesuf *et al.*, 2008; Matui, 2009). Even when such studies emphasize adjustment of agricultural practices to changing climate in semi-arid environments, they rarely identify location-and production system-specific farm-level adaptation strategies.

Much of the literature review on agricultural adaptation to climate change has drawn attention to a range of factors affecting the speed of adoption among small-scale households. A vast number of such studies identify household and farm characteristics and institutional factors as the key determinants of adoption (Adesina & Forson, 1995; Maddison, 2006; Marenya & Barrett, 2007; Nkonya *et al.,* 2008; Shiferaw et al., 2009; Gbetibouo, 2009; Ochieng et al., 2012; Gbegeh & Akubuilo, 2012). However, there is a paucity of information on the process of adaptation decision making among farmers. Identifying how and when to adapt agriculture to climate change in semi-arid environments remains far from clear. Moreover, the adoption literature examines factors influencing uptake of soil management practices in high potential agricultural areas(Tizale, 2007; Marenya & Barrett, 2007; Adolwa *et al*., 2012). However, there is limited information on adoption of off-farm livelihood strategies and other adaptive mechanisms that farmers use to circumvent the welfare impact of climate change in Kenya. Hence, this study was designed to make a contribution towards bridging the gap.

2.6 Theoretical Framework

This study is informed by the capability theory (Sen, 1999, 2004; Nussbaum, 2003, 2011) and random utility maximization theory (McFadden, 1974; Cascetta, 2009).

2.6.1 Capability theory

The theory examines capacities necessary for people to lead functioning lives. A person's functionings reflect the collection of "beings" and "doings", and can be viewed as various outcomes a person may achieve (Goerne, 2010). The central argument of this theory is the need to judge just arrangements in distributive terms, and how they affect the ultimate well-being and functioning of people's lives. The central question about justice is what we are actually able to do and be – it is not about commodities or the total/average GDP, but how they enable us to function (Nussbaum, 2011). A capability approach focuses on whether or not people possess capacities necessary to construct a fully functioning life. Such capacities are supported by among others, natural systems that directly depend on a stable climate system.

Capabilities approach provides concepts that can encompass the current framing of climate justice, but in a way that is more applicable to the development of adaptation policy (Schlosberg, 2011). Since this approach addresses the basic requirements that are necessary for human life to function and flourish; it is important to align adaptation policies with climate justice that protects the basic functioning of human communities, including the environment.

Changes in climate will affect what individuals are able to do with the resources that they have. If climate change impedes agricultural practices, or/and undermines local infrastructure, then functioning will be limited. In that case, climate change is a barrier to functioning lives (Schlosberg, 2009). Similarly, potential mental health impacts, such as the increased stress of those made climate refugees, and the overall anxiety of rapid climate change, could be seen as a barrier to capability of emotional health (Nussbaum, 2011).

Crucially, a capabilities-based approach to adaptation is not a top-down, expert-driven affair. Rather, communities need to be thoroughly involved in defining their own vulnerabilities and designing just adaptation policies that are planned to shield them from climate change that threatens their ability to function (Schlosberg, 2009; Ribot, 2010). Thus the approach offers a way of analyzing the particular needs of communities, of identifying gaps which hinder people to adapt to climate change, of directing adaptation policy toward preserving or rebuilding the specific capabilities under threat from climate change, and of measuring the success of implemented adaptation policies.

2.6.2 The Random Utility Maximization Theory

The decision to use any adaptation option falls under the frame-work of random utility theory. According to this framework, people choose what they prefer, and where they do not is influenced by random factors (McFadden, 1973). Thus, the utility of a choice is comprised of deterministic and an error components. The error component is independent of the deterministic part and follows a predetermined distribution. This shows that it is not usually possible to predict with certainty the alternative that the decision-maker will select. However, it is possible to express probability that the perceived utility associated with a particular option is greater than other available alternatives (Luce, 1959; Cascetta, 2009).

The utility U that individual i gains from the consumption of a good j is made up of an observable deterministic component V (the utility function) and a random component ε, and can therefore be defined as follows:

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

According to Cascetta (2009), we assume that utility U depends on choices made from some set of j adaptation options. The individual is assumed to have a utility function of the form:

$$U_{ij} = V(X_j, Z_i) \qquad (3.2)$$

A rational farmer who seeks to maximize the present value of benefits of production over a specified period of time must choose among a set of j adaptation options. The farmer i will use j adaptation option if the perceived benefit from that option is greater than the utility from other option k *if* $U_j > U_k$. Utility derived from any adaptation option is assumed to depend on the attributes of the adaptation option itself X_j and the socio-economic characteristics of the farmer Z_i (Cascetta, 2009). However, a farmer may not choose what seems to be the preferred adaptation option. To explain such variations in choice, a random element, ε is included as a component of utility function. Equation 3.2 can then be re-written as:

$$U_{ij} = V(X_j, Z_i) + \varepsilon(X_j, Z_i) \qquad (3.3)$$

The probability that farmer i will choose adaptation option j among the set of adaptation options k could be defined as follows:

$$\begin{aligned} Pr[i|CS] &= Pr[U_j > U_k], \quad \forall j \in CS \qquad (3.4) \\ &= Pr[(V_j + \varepsilon_j) > (V_k + \varepsilon_k)] \\ &= Pr[(V_j - V_k) > \xi] \end{aligned}$$

Where CS is the complete choice set of adaptation option. In order to estimate equation 3.4, assumptions must be made over the distributions of the error terms. A typical assumption is that the errors are Gumbel-distributed and independently and identically distributed (McFadden, 1973).

2.7 Conceptual Framework

The conceptual framework presented in Figure 2.1 shows the linkages between climatic variables, crop yields, adaptation strategies and policy framework and institutions. Exposure to climate variability and change affects livelihood patterns and autonomous adaptation strategies. The framework illustrates how policies and institutions directly influence planned adaptation to impacts and vulnerabilities. Planned adaptation reduces vulnerability of households and builds resilience to climate extremes through the adoption of climate-smart agricultural technologies.

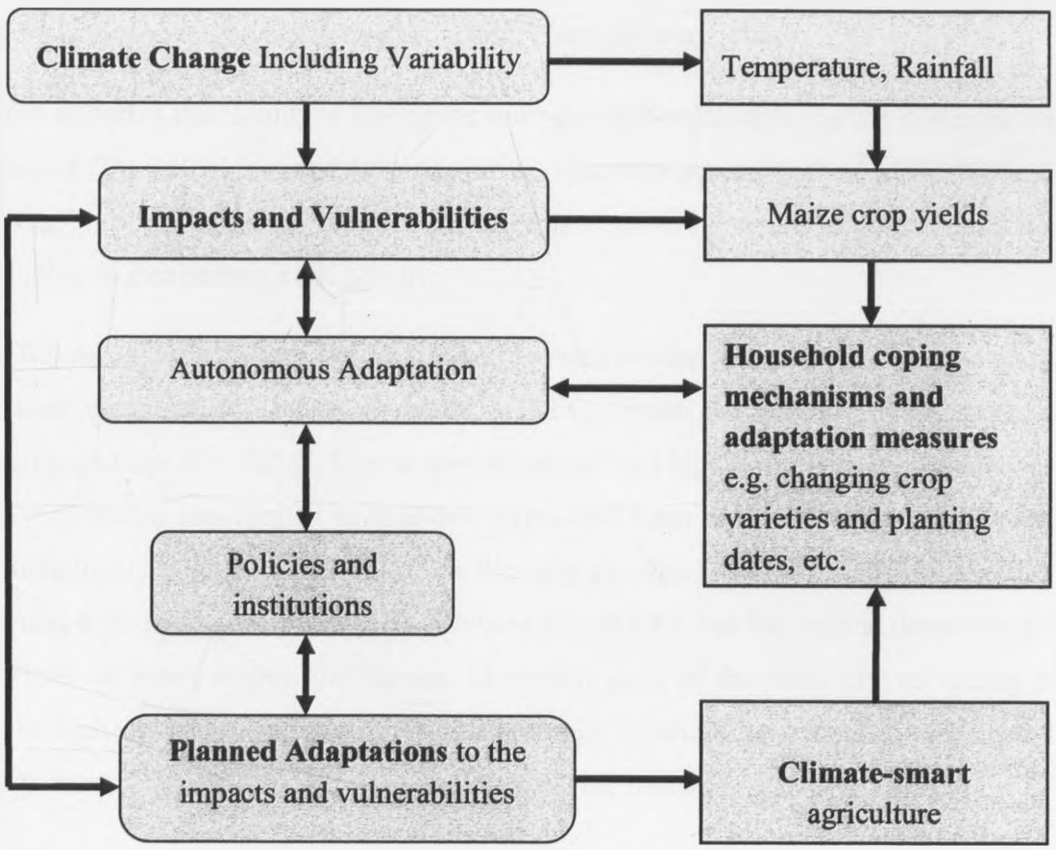


Figure 2.1: Conceptual framework showing steps involved in planned agricultural adaptation to climate change and variability

(Source: Modified from Smit & Olga 2001; O'Brien *et al.* 2007).

CHAPTER 3: METHODOLOGY

3.1 Study Site

This study was carried out between August and December 2012 in Kitui County on the lower eastern parts of Kenya. It borders four Counties, i.e. Machakos and Makueni to the west, Tana River (east) and Taita Taveta (south). The County comprises eight electoral constituencies, and covers an area of approximately 30,497Km² of which 690Km² is in the Tsavo East National Park (ROK, 2009). The altitude of the County ranges between 400 and 1800m above mean sea level. The Central part of the County is characterized by undulating plateau at about 1,100m, surmounted by hilly and ridges which rise to 1,700m (Jaetzold *et al.*, 2006).

As a semi-arid region, Kitui County is among the most drought-vulnerable regions in Kenya with annual rainfall of 500 – 1050 mm and 40% reliability. There is a general decline of rainfall in the main season of April/May. On the other hand, there is a general positive trend for short rains during September to December (ROK, 2010).

The periods falling between June to September and January to March are usually dry. The annual mean minimum temperatures range from 22 – 28°C, while the annual mean maximum temperatures range from 28 – 32° C. Due to limited rainfall and high temperatures, surface water sources are very scarce and limited to seasonal rivers that form during the rainy seasons and drying up immediately after rains. River Athi is the only perennial river in the region and flows along the border with Machakos County. The County has no lake, but has several dams that play a significant role in water supply and storage. However, most of the dams dry up during dry season due to high evapo-transpiration rates and seepage (ROK, 2010). Kitui County had an estimated population of 1,012,709 people, and over 205, 491 households (ROK, 2009).

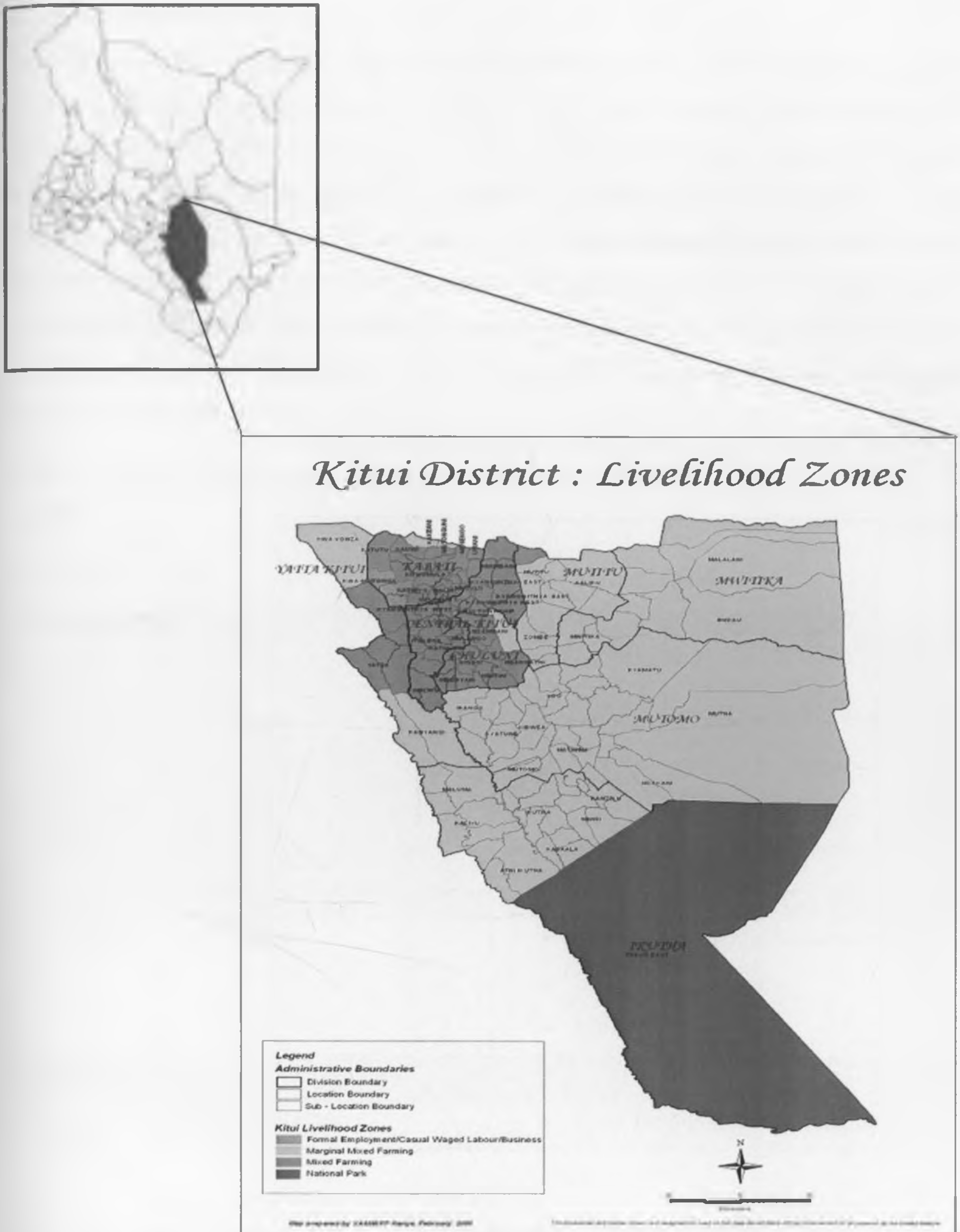


Figure 3.1: Map showing the administrative boundaries and livelihood zones of Kitui region in Kenya

3.2 Data Collection

The field study was conducted from August to December 2012 where interviews with key informants, focus group discussions (FGDs) with farmers, and household questionnaire survey were undertaken. Key informant interviews were conducted with a broad variety of stakeholders comprising public and private agencies. The term "key informant" in this study refers to a person who disposes specific competence/knowledge in/of climate change, its impacts and response mechanisms due to academic qualifications or/and many years of work experience. The interviews were aimed at getting insights into macro level policies and trends in the County and their capacity to respond to climatic shifts and variations. During the field study, fifteen key informants were interviewed.

Table 3.1: Organisations represented in key informants interviews

Organisation Type	Name of the Organisation
Government extension	• Provincial Administration • Ministry of Agriculture • The National Drought Management Authority • The Forestry Department • The National Environment Management Authority
Local NGOs	• The Catholic Arch-Diocese of Kitui • Sahelian Solutions • Maarifa Centre
International NGOs	• Red Cross
Community Based Organisations	• Kitui Development Community

The second stage consisted of focus group discussions (FDGs) with local elders, chiefs/sub-chiefs, religious leaders, professionals, agricultural extension officers, and representatives of women's and youth groups. Twelve participants were identified through the area chiefs and asked to identify their peers in a snowballing sequence. FGDs were used to assess the community's perceptions of climate change; trends in weather patterns; impacts of climate change on their livelihoods and how they are coping and adapting to the impacts.

The final stage involved household survey using semi-structured questionnaires that provided the basis for a quantitative characterization of household's socio-economic characteristics, farmer perceptions of climate change and coping mechanisms. Household adaptive capacity and sensitivity levels were measured by proxy using indicators such as levels of education, levels of income, mean household size, access to water and food security. During household survey, farm data on soil and water management were obtained through direct field observation.

Policy documents from Ministries of Agriculture and environment, Meteorological Department, National Drought Management Authority and National Environment Management Authority (NEMA), and future climate scenarios from IGAD Climate Prediction and Applications Centre (ICPAC) and IPCC were reviewed to enable the development of instruments. The review further enhanced the understanding of climate change adaptation and vulnerability. The study used Satellite Rainfall Estimation (RFE) data from the National Drought Management Authority for the period between 1996 and 2012. Maize crop yield data for Mutomo district, for the same period was obtained from the ministry of agriculture. Different sets of instruments were developed and pre-tested to meet the objective of this study. These include household survey questionnaires and key informant interview guides.

3.3 Sampling Techniques

A combination of multi-stage sampling and simple random sampling was used to select the villages and households where questionnaire survey was carried out. The study area comprising three administrative districts was stratified into three agro-ecological zones, namely: lower midland marginal cotton zone (LM4), lower midland livestock–millet zone (LM5), lowland livestock–millet zone (L5) (Jaetzold & Schmidt, 1983). From each zone, rural population of households, based on National Population and housing Census results (ROK, 2009), were used to randomly select 322 household heads (Table 3.2).

Table 3.2: Distribution of households sampled per agro-climatic zone

District	Agro-Ecological zone	Number of households
Mutomo	Lower midland livestock–millet zone (LM5)	113
Ikutha	Lowland livestock–millet zone (L5)	113
Lower Yatta	Lower midland marginal cotton zone (LM4)	106

To determine the sample size needed to measure a given proportion with a degree of accuracy at a given level of statistical significance, the following formula (NEA, 1960) was employed:

$$s = X^2NP(1-P) \div d^2(N-1) + X^2P(1-P)$$

Where:

s = required sample size.

X^2 = the table value of chi-square for 1 degree of freedom at the desired confidence level

(3.841).

N = the population size.

P = the population proportion (assumed to be .50 since this would provide the maximum sample size).

d = the degree of accuracy expressed as a proportion (.05).

Based on 2,000 households in sampling areas in Kitui County, 322 farmers were selected for this study. An addition 5% was included to cover for the anticipated non-responses and fouled questionnaires and to increase the power of the study giving a total of 338.

3.4 Data Analysis

To determine the actual meteorological status, a 17-year rainfall data was analysed for trends and anomalies. The data was then subjected to a correlation analysis to determine any association between rainfall and maize crop yields during that period. A regression analysis was then undertaken to show attribution of climatic changes to crop production.

Data from household survey was subjected to descriptive analysis to give frequencies and proportions. A one-way analysis of variance (ANOVA) was then applied to compare household variables between three districts. Such variables included age of household heads, schooling years, frequency of extension service, distance to nearest markets and water sources, land sizes, and the number of food deficient months. For each component, statistically different means were separated using least significance difference (LSD) at 5% level ($p < 0.05$). A chi-square (χ^2) test was used to inspect for relationships between mean monthly incomes and household choice of cooking fuel, marital status, and income distribution among respondents across the districts.

The determinants of perception and adaptation were examined using Heckman probit and multivariate biprobit (MVBP) models (Maddison, 2006; Nhemachena & Hassan, 2007; Kassie et al., 2012). Both models were estimated using statistical software Stata version 10.0. The Heckman probit model determines the likelihood of perceiving any change in the climate as well as the likelihood of farmers' adapting to these changes. Not every farmer who perceives climate change will respond by taking adaptation measures. Here it was argued that farmers who perceived climate changes and responded share some common characteristics.

3.5 Model for Empirical Analysis

- **Heckman sample selectivity model**

Adaptation to climate change begins with perceiving climate change, and then deciding whether to adapt or not (Maddison, 2006). Thus, the correct modeling of adaptation behavioural to climate variability and change implies the use of sample selectivity model (t=0, perception of climate change; t=1, adaptation option is made) (Gbetibouo, 2009).

Heckman's sample selectivity probit model is based on the following two latent variables

$$Y_1 = b'X + U_1$$

$$Y_2 = g'Z + U_2$$

where X is a k-vector of regressors; Z is an m-vector of regressors, possibly including 1's for the intercepts; and the error terms U_1 and U_2 are jointly normally distributed, independently of X and Z, with zero expectations. The latent variable Y_1 is only observed if $Y_2 > 0$. Thus, the actual dependent variable is:

$$Y_1 = if\ Y_2 > 0, \qquad Y \text{ is a missing value } Y_2 \leq 0 \qquad (1)$$

The latent variable Y_2 itself is not observable, only its sign. $Y_2 > 0$ if Y is observable, and $Y_2 \leq 0$ if not. Without loss of generality, U_2 can be normalized such that its variance is equal to 1. If we ignore the sample selection problem and regress Y on Z using the observed Y's only, then the ordinary least squares (OLS) estimator of b will be biased, because

$$E[Y_1/Y_2 > 0, X, Z] = b'X + rsf(g'Z)/F(g'Z) \qquad (2)$$

where F is the cumulative distribution function of the standard normal distribution, f is the corresponding density, S^2 is the variance of U_1, and r is the correlation between U_1 and U_2. Hence,

$$E[Y_1/Y_2 > 0, X,] = b'X + rsE[f(g'Z)/F(g'Z)/X] \qquad (3)$$

The latter term causes sample selection bias if r is non-zero. In order to avoid the sample selection problem, and to get asymptotically efficient estimators, the model parameters are estimated by maximum likelihood (Gbetibouo, 2009).

- **Multivariate biprobit model**

Given that several adaptation choices were investigated, the appropriate economic model would be either multivariate biprobit (MVBP) or multinomial logit (MNL) regression models. Both models estimate the effect of independent variables on a dependent variable involving multiple choices with unordered multiple categories (Gbetibouo, 2009). However, in this study, MVBP was preferred because it simultaneously models the influence of the set of explanatory variables on each of the different adaptation choices, while allowing the unobserved and/or unmeasured factors (error terms) to be freely correlated (Lin, Jensen & Yen, 2005). One source of correlation may be complementaries (positive correlation) and substitutabilities (negative correlation) between different adaptation options (Belderbos et al., 2004).

In contrast to MVBP models, univariate probit models ignore the potential correlation among the unobserved disturbances in the adoption equations, as well as the relationships between the adoptions of different farming practices. Farmers may consider a combination of adaptation options as complementary and others as competing. Failure to capture unobserved household-specific factors and inter-relationships among adoption decisions regarding different adaptation measures will lead to bias and inefficient estimates (Nhemachena & Hassan, 2007; Kassie et al., 2012).

The multivariate probit econometric approach used for this study is characterized by a set of n binary dependent variables y_i(with observation subscripts suppressed), such that:

$$y_i = 1 \; if \; x'\beta_i + \varepsilon_i > 0,$$
$$= 0 \; if \; x'\beta_i + \varepsilon_i \geq 0, i = 1,2, \ldots, n, \qquad (1)$$

where x is a vector of explanatory variables, $\beta_1, \beta_2, \ldots, \beta_n$ are conformable parameter vectors, and random error terms $\varepsilon_1, \varepsilon_2, \ldots \varepsilon_n$ are distributed as multivariate normal distribution with zero means, unitary variance and an $n^x n$ contemporaneous correlation matrix $R = [\rho_{ij}]$, with density $\emptyset(\varepsilon_1, \varepsilon_2, \ldots \varepsilon_n; R)$.

The likelihood contribution for an observation is the n-variate standard normal probability

$$\Pr(y_1, \dots y_n | x = \int_{-00}^{(2y_1-1)x'\beta_1} \int_{-00}^{(2y_2-1)x'\beta_2} \dots \times \int^{(2y_n-1)x'\beta_n} \emptyset(\varepsilon_1, \varepsilon_2, \dots, \varepsilon_n; Z'RZ) d\varepsilon_n \dots d\varepsilon_2 d\varepsilon_1, \quad (2)$$

where Z =diag$[2y_1 - 1, \dots ;2y_n - 1]$. The maximum likelihood estimation maximizes the sample likelihood function, which is a product of probabilities (2) across sample observations (Nhemachena & Hassan, 2007).

3.6 Ethical Considerations

The permission to administer household questionnaires and conduct key informant interviews was consensual. If the respondents demonstrated or articulated discontent, the interviews were re-scheduled or cancelled. Respondents were presented with the consent form requesting for their authorisation. Besides, they were informed beforehand that should parts of their interview be used in a publication, their name will not be recorded and any details related to their privacy will be kept confidential.

The benefits from this study which involve building resilience and reducing vulnerability in semi arid communities were well explained to the respondents. This justification enhanced respondents' interests in this research. After compilation of the final report, copies will be made available to those informants who request them.

CHAPTER 4: RESULTS

This study found that Kitui region is experiencing depressed rainfall and multi-year droughts as a result of climate variabilty and change (Figure 4.2). This has a major impact on small-scale agro-pastoralists whose livelihoods depend on natural resources: primarily water, land, and its bio-diversity. Although most households have developed various adaptation measures to climate change, the choice of such measures varies across space and is largely determined by socio-economic and institutional factors.

4.1 Effects of Rainfall on Maize Crop Yields

4.1.1 Rainfall Patterns and Trends

Between 1996 and 2012, a mean annual rainfall of 501mm was recorded. This included 180 mm for long rains and 236 mm for the short season. Rainfall was characterised by large intra-and inter-annual variability (Figure 4.1) with a significant negative trend of 34 mm per year (y = -34.272x +691.82, R^2 = 0.5264, $P < 0.001$) in mean annual values. This trend was true for both long (y = -12.039x +243.07, R^2 = 0.4393, $P < 0.001$) and short (y = -14.434x +291.62, R^2 = 0.1995, $P < 0.001$) rains.

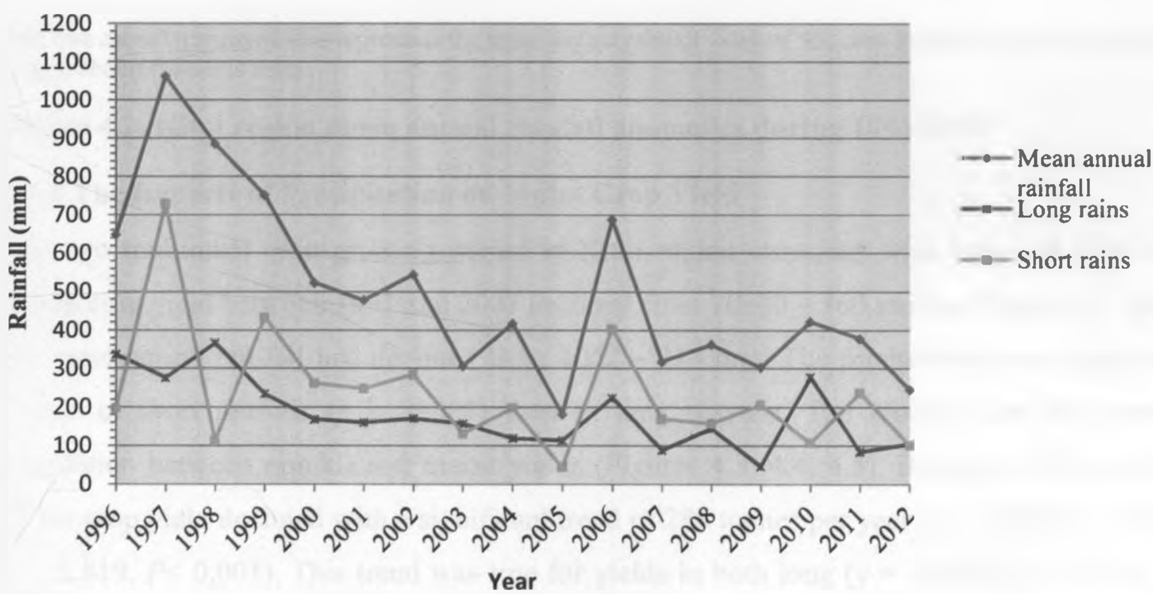
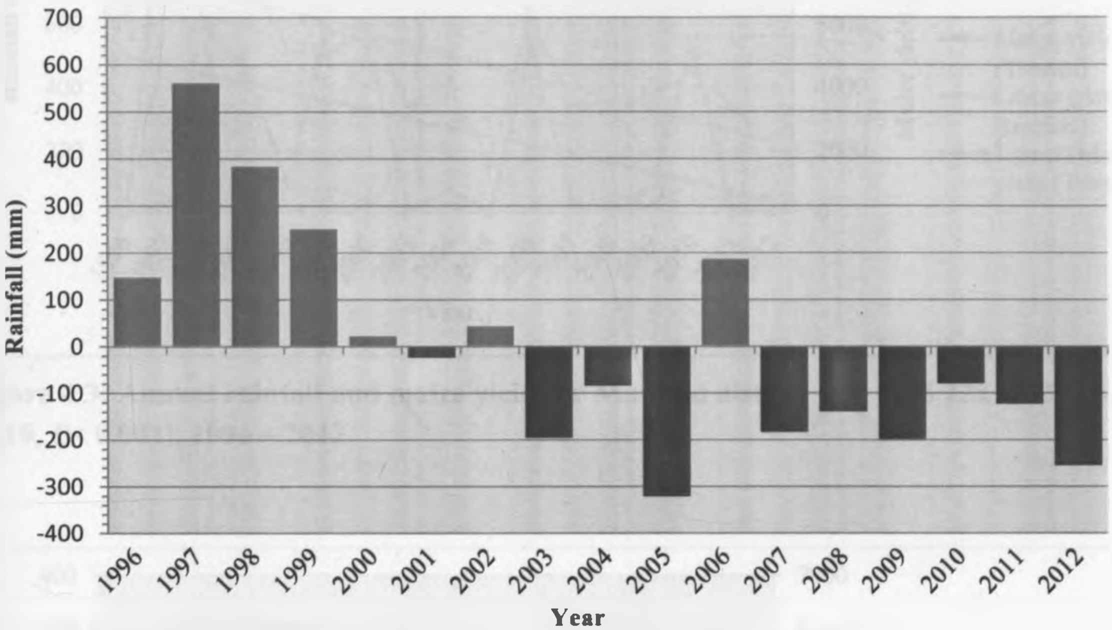


Figure 4.1: Total annual and seasonal rainfall trends for Kitui region (y = -34.272x +691.82, R^2 = 0.5264, $P < 0.001$), Long rains (y = -12.039x +243.07, R^2 = 0.4393, $P < 0.001$), Short rains (y = -14.434x +291.62, R^2 = 0.1995, $P < 0.001$), 1996-2012

During this period, above average rains were recorded for seven years and below average for 10 (Figure 4.2). In the period between 2003 and 2012, the region recorded cumulatively 1391 mm below long-term mean.



NB: The cut-off horizontal axis represents the mean annual rainfall value of 501 mm. Each bar represents rainfall excess/deficit from this norm.

Figure 4.2: Kitui region mean annual rainfall anomalies during 1996-2012

4.1.2 The Impacts of Precipitation on Maize Crop Yield

The two traditional crop growing period in Kitui region coincides with long and short rains. Maize crop yield between 1997 and 2007 declined from 10800 – 360 tonnes (Figure 4.3). During the same period rainfall had declined from 1062 – 318 mm. The productivity was significantly higher in short seasons (p ▯ 0.001) than in long seasons. The results show high positive correlation between rainfall and maize yields (Figures 4.3, 4.4, 4.5). Between 1996 and 2012, maize crop yield declined with a significant trend of 285 tonnes per year ($y = -285.22x + 5277.6$, $R = 0.819$, $P < 0.001$). This trend was true for yields in both long ($y = -59.559x + 1515.4$), $R = 0.704$, $P < 0.001$) and short (y $-225.66x + 3762.1$, $R = 0.836$, $P < 0.001$) seasons.

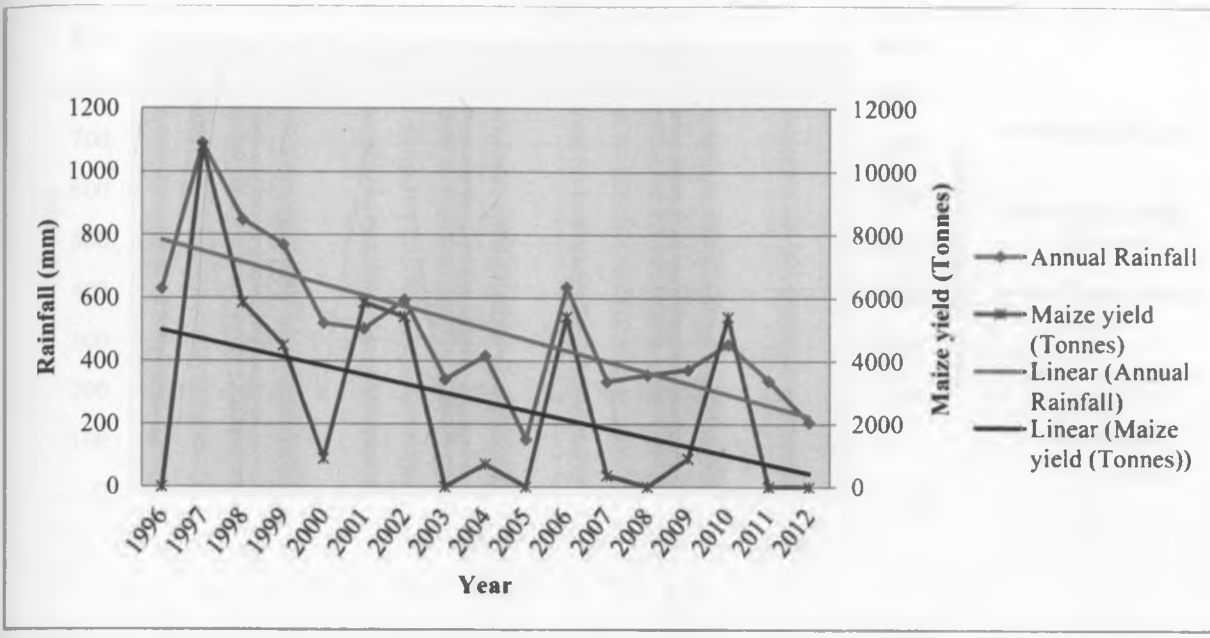


Figure 4.3: Annual rainfall and maize yield for Mutomo district (y = -285.22x + 5277.6, *R* = 0.819, *P*< 0.001), 1996 – 2012

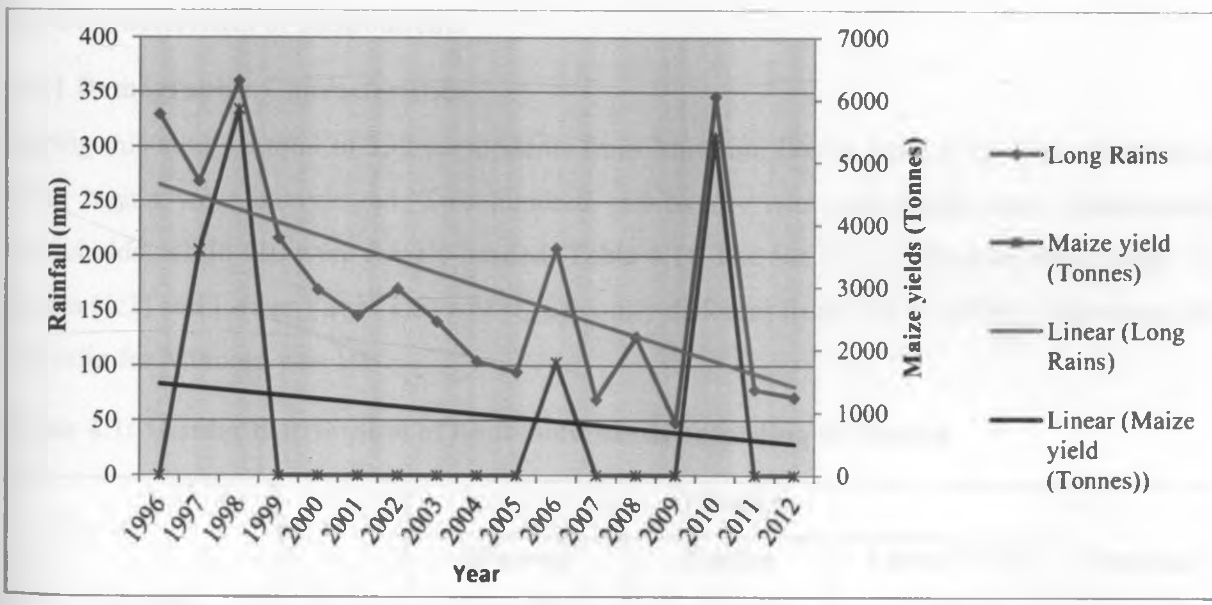


Figure 4.4: Long seasonal rains and maize yields for Mutomo district (y = -59.559x + 1515.4), *R* = 0.704, *P*< 0.001), 1996 – 2012

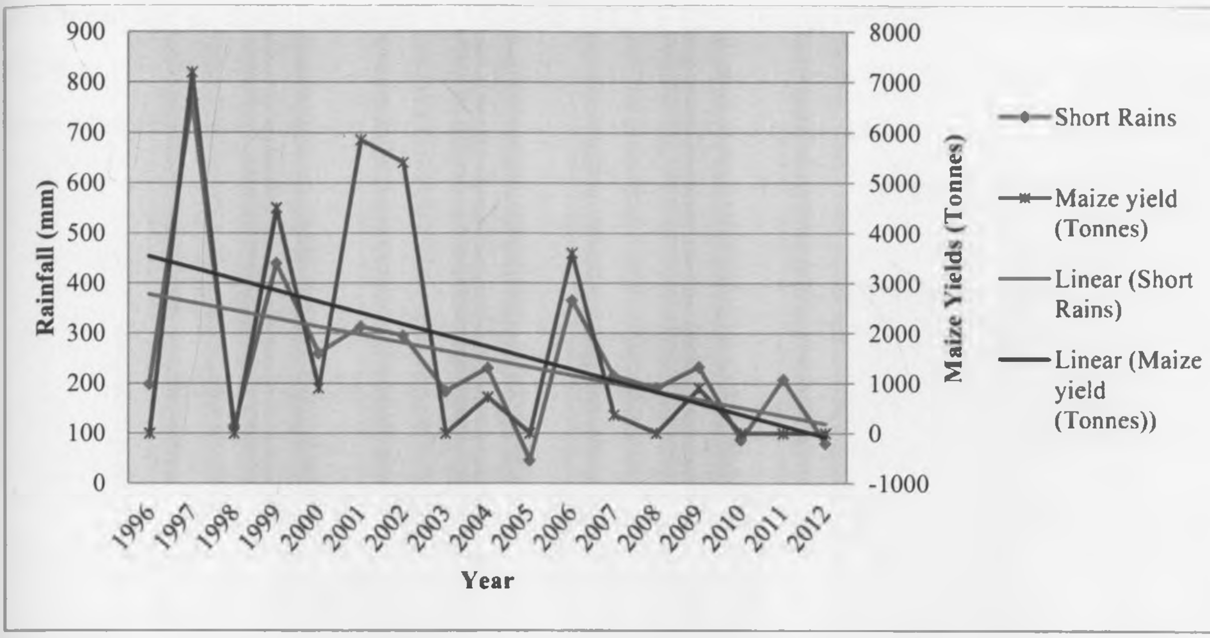


Figure 4.5: Short seasonal rains and maize yield for Mutomo district (y -225.66x + 3762.1, R = 0.836, P< 0.001), 1996 – 2012

4.2 Characteristics of Respondents

4.2.1 Demographic Characteristics

During this study, a total of 332 respondents from Mutomo, Ikutha and Lower Yatta districts in Kitui region were interviewed. Two hundred and twenty two respondents were male-headed households, while 110 were female-headed (Table 4.1). The sex ratio of the household heads for Ikutha (1:2) and Lower Yatta (1:5) was significantly different from 1:1($p < 0.001$). However, the sex ratio for Mutomo was 1:1

Table 4.1: Gender distribution of household heads according to district

Variable		Districts						Regional average
		Mutomo (n = 113)		Ikutha (n = 113)		Lower Yatta (n = 106)		
		Freq.	%	Freq.	%	Freq.	%	%
Sex	Male	57	50	76	67	89	84	67
	Female	56	50	37	33	17	16	34

The mean age of the respondents in Mutomo (41.6 ± 0.9), Ikutha (46.6 ± 0.9) and Lower Yatta (52.8 ± 1.2) districts were significantly different (P ▯ 0.001, F = 30.13, n = 3). Respondents from Mutomo were youngest and from Lower Yatta oldest (Figure 4.6).

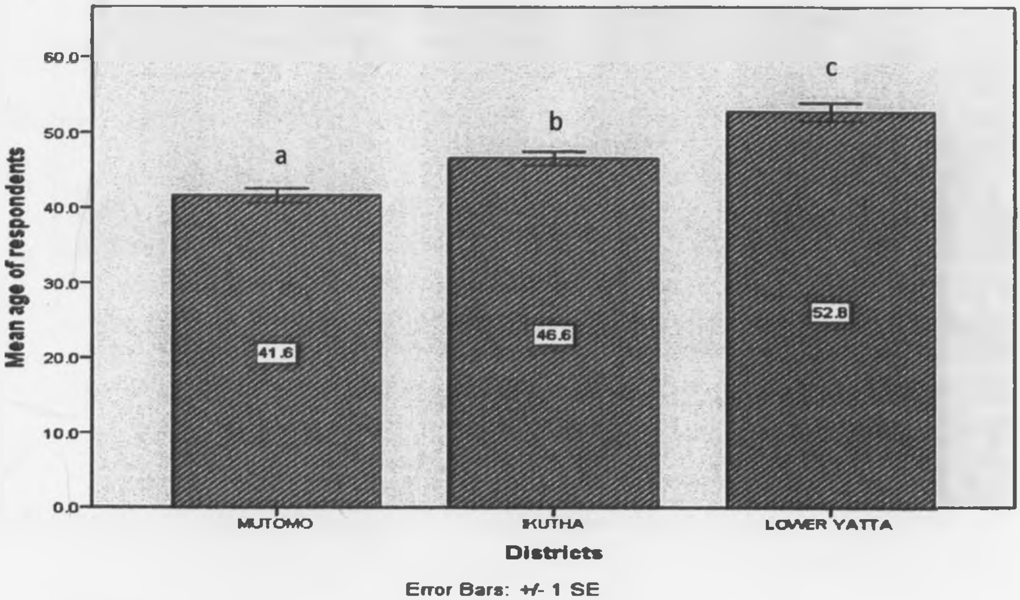


Figure 4.6: The mean age of household heads in Mutomo, Ikutha and Lower Yatta districts were significantly different and separated using letters (a, b, c) at $p < 0.001$

Most farmers (79%) in the study areas were married, 11% were single, while 8% were widowed. Only 3% were either divorced or separated from their spouses. Mutomo district had the highest proportion of the single farmers at 13%. The marital status across districts were similar.

About eight percent of respondents had no formal education, 16% had attained four years of schooling, while 23% had eight years. Twenty five percent and 21% of the respondents had attained twelve years and fourteen years of schooling, respectively. Only 7% had graduate qualification

Gender disparities in the attainment of education at different levels of schooling in Kitui region was significant ($P < 0.000$, $F = 27.46$, $n = 2$). Male household heads had attained more years of schooling than their female counterparts (Figure 4.7). Across the districts, household heads from Lower Yatta and Ikutha had more schooling years than were those from Ikutha. The average years of schooling were 10.62 in Lower Yatta, 10.27 in Ikutha and 9.42 in Mutomo.

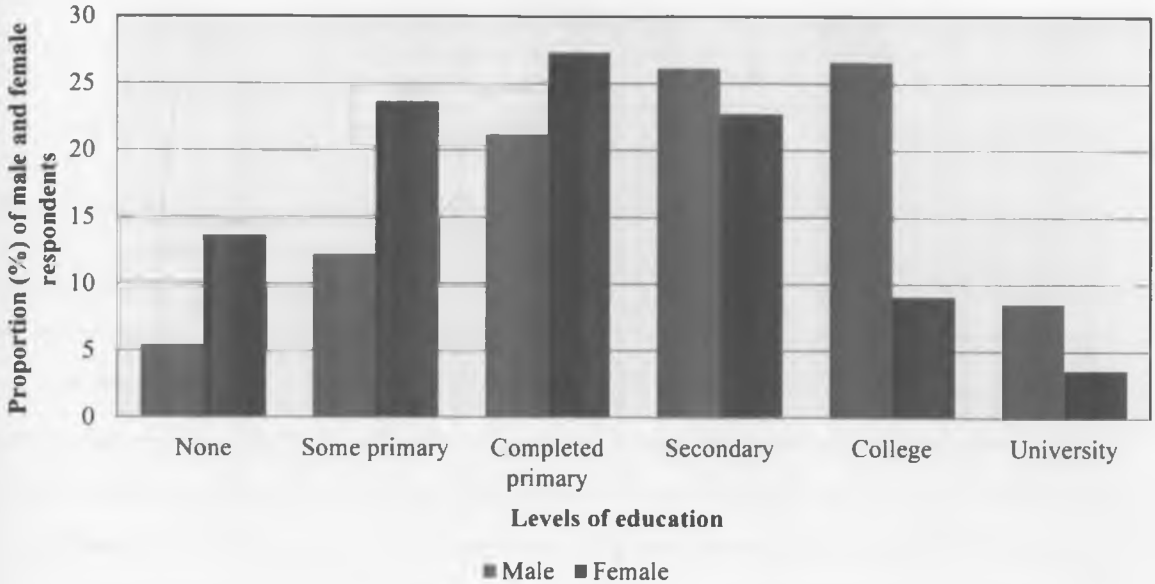


Figure 4.7: The distribution of male and female respondents by levels of education

4.2.2 Socio-Economic Characteristics

The main assets in the community include land, farm equipments (e.g. jembes, hoes, ox ploughs and pangas), livestock (e.g. donkey, poultry, goats, few cattle and sheep), other household assets (e.g. radio, cart, torch, mobile phones), and bicycles which is a key means of transport. Livestock is predominantly local breeds, with very few improved poultry.

Table 4.2: Summary of socio-economic variables

Variables		Districts			Regional Average
		Mutomo (*n* = 113)	Ikutha (*n* = 113)	Lower Yatta (*n* = 106)	
		%	%	%	%
Sources of income	Crop Farming	50	30	27	36
	Business	27	30	26	27
	Pastoralism	1	3	4	3
	Salary	18	17	28	21
	Wages	2	16	10	9
	Remittance	1	3	3	2
	Others	1	1	3	2
Type of housing	Mud walled grass thatched	10	20	5	12
	Semi permanent with iron sheets	68	53	55	58
	Permanent stoned walled	22	27	41	30
Mean monthly income	Up to Ksh 10,000	85	83	68	79
	10,001-30,000	11	11	19	13
	30,001-50,000	3	3	9	5
	Over 50,000	2	2	4	3
Main cooking fuel	Firewood	91	90	85	89
	Charcoal	7	10	10	9
	Kerosene	2	0	3	2
	Crop residues	0	0	1	0
	Others	0	0	1	0

Thirty six percent of the households depended on crop farming as the principal source of income (Table 4.2). The situation was found to be similar between districts. Other main sources of income are salaried employment (30%) and business activities (27%). Pastoralism ranks very low (2%) as a source of income. The sources of income across different districts were similar.

Other income generating activities pursued in the study areas include operating motorcycles taxis, sand harvesting, brick-making, charcoal making, water vending and bee keeping.

Seventy nine percent of respondents had a mean monthly income of less than Ksh. 10,000, thirteen percent had between Ksh 10,001 and 30,000, while 5% had between 30.001 and 50,000. Only three percent had a monthly income above Ksh 50,000. However, in Lower Yatta district, nine percent of the sampled farmers had a mean monthly income between Ksh 30,000 and 50,000 (Table 4.2).

Eighty nine percent of the households use firewood as the source of fuel for cooking, while nine percent use charcoal (Table 4.2). There was no relationship between mean monthly income and household choice of cooking fuel. Most (58%) homesteads in the study area have semi permanent houses with iron sheet roofing, 30% have stone walled permanent, while 12% have mud walled grass thatched houses (Table 4.2). Forty one percent of the sampled respondents with permanent stoned walled houses are business people, while 37% are those in salaried employment such as teachers and civil servants. In contrast, 51% of the respondents with mud walled grass thatched houses are farmers.

Seventy two percent of respondents belonged to different social and economic groups (Figure 4.8). These groups are organised along environmental issues (water, grazing land, and arable land), economic issues (saving, credit, crop farming, and livestock) and social issues (health, literacy, sport, religion).

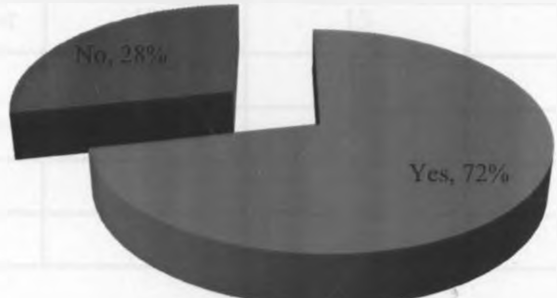


Figure 4.8: Distribution of households by affiliation to a social group

4.2.3 Institutional Factors

Seventy three percent of respondents had direct contact with extension services for past one year, while 27% did not have access to extension services within the year. Sixty percent of the respondents had weekly and monthly access to extension services, while 14% had access to extension once a year. The situation was the same across the districts. However, in Ikutha district, 23% of the farmers had less frequent access of only one visit a year, while Mutomo and Lower Yatta districts had 4% and 13%, respectively (Table 4.3).

Forty four percent of the total sample had access to Government extension service, 21% had access to NGOs, while 9% had access to private extension sources. The situation was similar across districts. However, in Lower Yatta district, only 11% of the sampled households had access to NGOs as a source of extension. Access to government extension is below 50% because the service is only provided on demand. This has pushed poor farmers to seek extension service from NGOs and other private sources.

Table 4.3: The frequency and sources of extension service to farmers

		Districts			Regional average
		Mutomo (*n* = 113)	Ikutha (*n* = 113)	Lower Yatta (*n* = 106)	
		%	%	%	%
Frequency of visit within a year	No visit	24	33	24	27
	Weekly	9	4	7	6
	Monthly	54	50	55	53
	Once a Year	13	13	14	14
Sources of extension	None	24	33	24	27
	Government	39	39	54	44
	Private	7	9	11	9
	NGOs	30	20	11	21

Most respondents (61%) live within a radius of between 1 and 10 km to the nearest market, 23% live in less than 1 km, while 17% live in over 10 km. The scenario was not the same across the districts with respect to farmers that reside over 10 km from the nearest market. For instance, in Ikutha and Lower Yatta districts, 28% and 9% of the respondents could access the market in over 10 km, respectively. However, the proportion of respondents that lived between a distance of 1 and 10km is relatively similar across the districts (Table 4.4).

Table 4.4: Distribution of households by the distance to the nearest market

		Districts			**Regional average**
		Mutomo (n = 113)	**Ikutha (n = 113)**	**Lower Yatta (n = 106)**	
		%	%	%	%
Distance to the nearest Market	Less than 1km	22	20	26	23
	1 – 10 km	61	63	58	61
	Over 10km	17	18	16	17

4.3 Farm Characteristics

4.3.1 Land Ownership and Utilization

The mean land size owned by the farmers in Mutomo, Ikutha and Lower Yatta districts was 3.7 (± 0.4), 7.0 (± 0.8) and 30.9 (± 4.6) acres, respectively (Figure 4.9). These values were significantly different ($P < 0.001$, $F = 33.9$, $n = 3$).

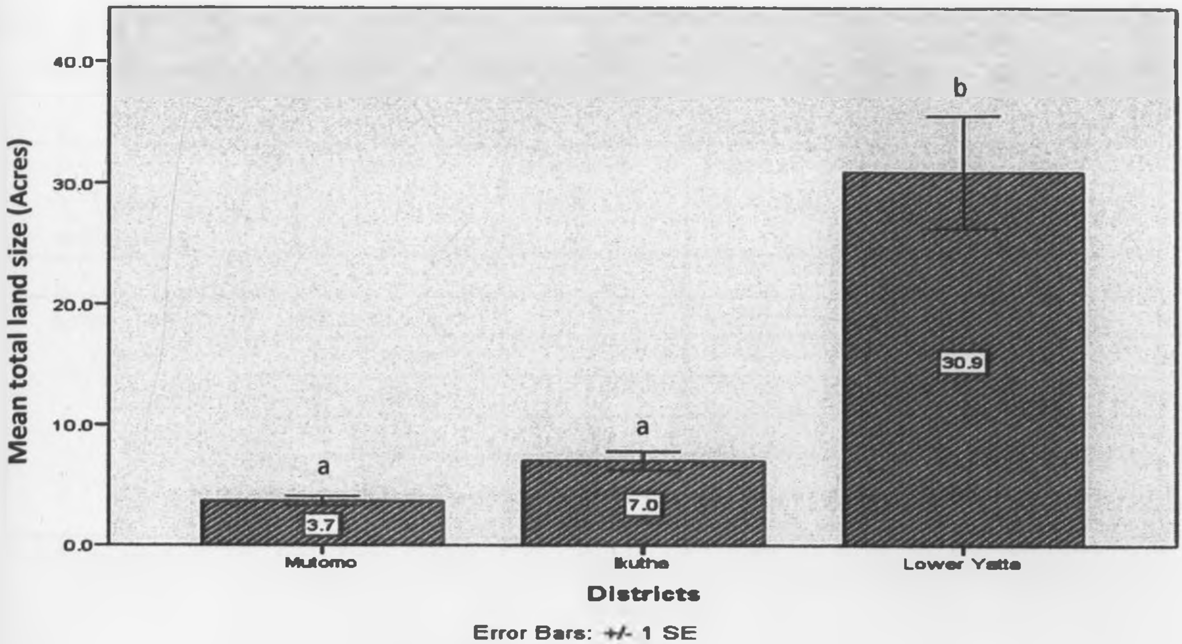


Figure 4.9: The mean land size for Lower Yatta district was significantly different from those of Mutomo and Ikutha. However, the mean values for Mutomo and Ikutha were statistically similar. Significantly different means are separated using letters (a, b) at $p <$ 0.001

Most households in the region (54%) grow crops in small farm sizes of between 1-3 acres. Only a small proportion (4%) grows crops in large farm sizes of over 10 acres. Similarly, most households had 4-5 acres (42%) of land under pasture, less than 1 acre (39%) and 1-3 acres (38%) under tree cover (Table 4.5). Most households (57%) set aside less than one acre of land for trees which are mainly used for brick-making, charcoal burning, and construction purposes. However, different social groups organised along environmental conservation have embarked on 'green programmes' through the establishment of tree nurseries. The Forestry department is providing tree seedlings to the local community at subsidised rates, besides sensitizing them on the importance of enhancing the tree cover. However, this noble effort of tree planting is hampered by frequent long dry spell.

Table 4.5: Summary of land utilization

Land utilization	Size of land	Districts			
		Mutomo (n = 113)	Ikutha (n = 113)	Lower Yatta (n = 106)	Regional average
		%	%	%	%
Area Under crops	Less than 1 acre	5	9	5	6
	1 – 3 acres	71	42	50	54
	4 – 5 acres	11	26	25	20
	6 – 10 acres	8	18	11	12
	Over 10 acres	4	2	7	4
	Don't know	1	4	3	3
Area under pasture	Less than 1 acre	48	19	12	27
	1 – 3 acres	35	46	53	45
	4 – 5 acres	4	14	12	10
	6 – 10 acres	4	12	10	8
	Over 10 acres	8	7	9	8
	Don't know	1	3	3	2
Area under tree cover	Less than 1 acre	57	35	25	39
	1 – 3 acres	31	34	49	38
	4 – 5 acres	4	11	8	8
	6 – 10 acres	4	11	8	8
	Over 10 acres	3	7	9	6
	Don't know	1	3	3	2

Most respondents (51%) had private ownership of land with title deeds, 44% had access to ancestral land, while 3% had access to land through communal tenure. Only 2% of respondents had access to land through leasehold.

4.3.2 Land Location

Majority of the households in the whole sample live in the plains and lowlands (79%) compared to 16% who lived in upland areas and 5% in river valleys. This is the situation in all districts (Table 4.6).

Table 4.6: Distribution of households per districts by land location

	Districts			
Farm Location	**Mutomo (n = 113)**	**Ikutha (n = 113)**	**Lower Yatta (n = 106)**	**Regional average**
	%	%	%	%
Uplands/Slopes	18	15	14	16
Lowlands/plains	79	80	79	79
River Valley	4	5	7	5

The households in the plains, lowlands and uplands were more vulnerable to drought which affected their agricultural productivity. Although river valleys are agriculturally productive, most of the households living in these areas were vulnerable to both flooding and drought which affected their agricultural productivity.

4.4 Environment and Food Security

4.4.1 Water access and availability

The main sources of water are earth dams, rivers and streams, shallow wells, boreholes, rain-water and piped water. These sources are not readily available making it necessary for people to travel far distances to fetch water. Water was accessible to 32% of the sampled households in more than 5 km, 26% between 1 and 3 km, while 22% and 20% in less than 1 km and between 4 and 5 km, respectively (Figure 4.10).

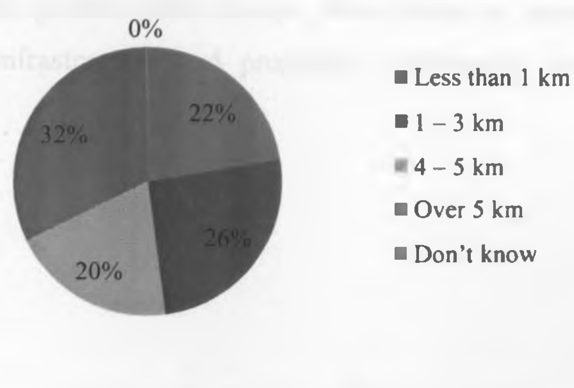


Figure 4.10: Distribution of households by the distance to the nearest water source

The proximity to water source was checked against the significant changes in weather observed over the past 20 years (Table 4.7): those who reported long distance to water had also observed prolonged drought (54%) and unpredictable rainfall (43%).

Table 4.7: Significant Changes in Weather and Nearest Water Sources

		Significant changes observed in weather over the past 20 years				
		Unpredictable rains	Prolonged drought	Very hot seasons	Very wet seasons	Don't know
		%	%	%	%	%
Nearest water source	▯ 1km	43	46	7	0	4
	1-3 km	37	56	5	0	2
	4-5km	33	59	6	2	0
	>5km	43	54	3	0	1
	Don't know	0	0	100	0	0

The respondents also pointed different problems in accessing water with most of them indicating long distances (41%), water scarcity (32%) and dirty water (22%) (Figure 4.11). Drying up of river beds, earth dams and shallow wells are the major challenges reported by households. Consequently, most households are forced to depend entirely on few boreholes located far away from their homes. However, the borehole water is mainly salty and polluted and thus a hub of many water-borne disease vectors and pathogens. At any given time, several people in community are suffering from one or more water related illness.

During focus group discussions (FGDs), it was suggested that the best way of resolving water access challenges would be enhanced harvesting and storage of rain water, tree planting and soil management schemes to enhance ground water storage, more access to piped water, increased access to funding for water infrastructure and promoting community awareness on water conservation.

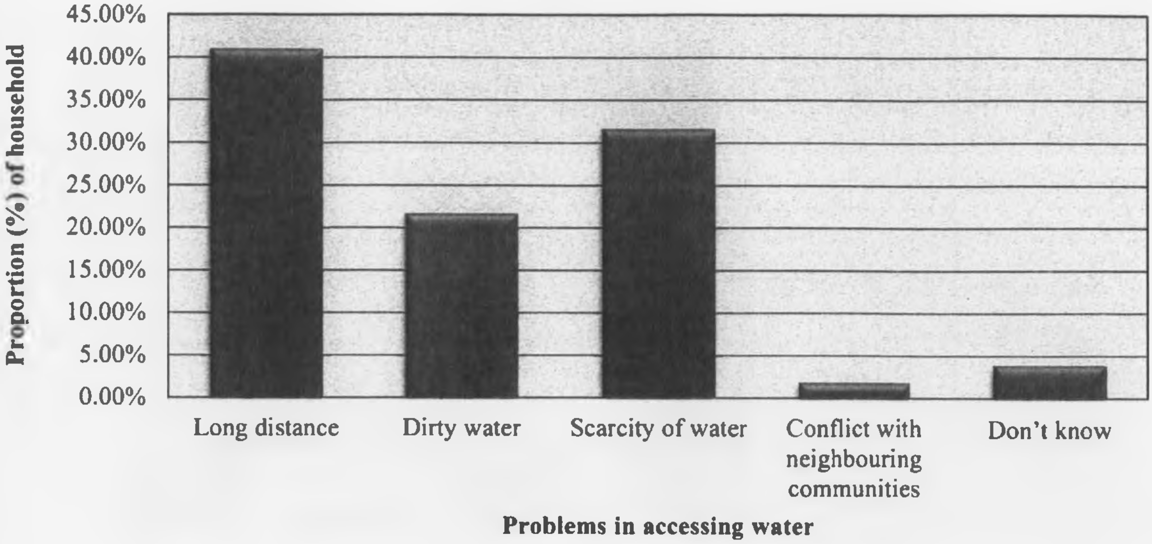


Figure 4.11: Problems experienced in water accessibility in Kitui County

4.4.2 Food Security and Agriculture

The main food crops grown by the respondents include maize, millet, peas, beans and sorghum. According to community members interviewed, planting seasons used to be standard and predictable. There were two planting seasons which would produce enough harvest to last till the next harvest. Presently, planting season has become unpredictable, resulting into depressed and unpredictable crop yields. Despite consistent campaigns by private and public agencies in favour of drought resistant crops such as millet and sorghum, people's attitude and taste have not changed with preference for maize and beans being dominant. Other challenges of food production include limited alternative use of traditional food crop and poor storage.

Access to food has become a challenge as 88% of the respondents said they were food insecure, and could not produce enough for their families, while only 12% are food secure. Similarly, 71% of the households experienced food deficient months of over 5 months, 13% between 4 and 5 months, and 4% in less than three months This has led to people surviving on only one meal per day resulting into hunger, malnutrition and other diet related illness. The number of food deficient months in a year is similar across the districts. However, in Lower Yatta, 16% of sampled households are food secure, while 10% and 12% are food secure in Mutomo and Ikutha, respectively (Figure 4.12).

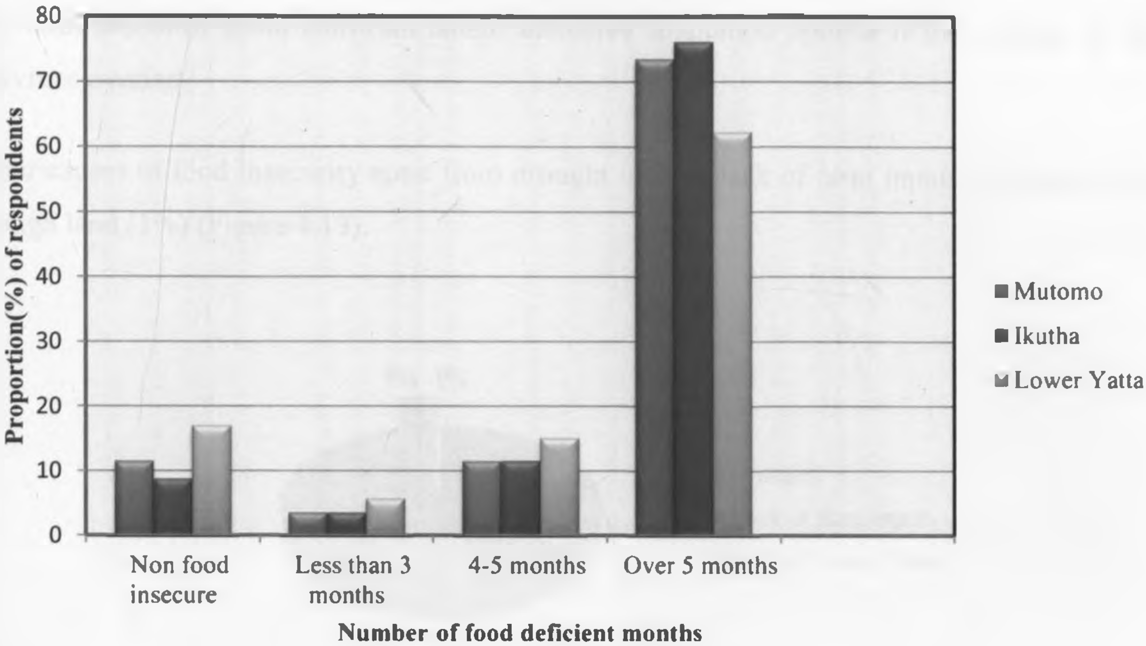


Figure 4.12: Distribution of households by the number of food deficient months

Policy actors in the district indicated that food insecurity has been a major problem among small-holder farmers. In the Kitui County, food scarcity worsens during periods of prolonged droughts. As a consequence of this, households have devised coping strategies such as engaging in intensive public works (for food or cash), reducing the number of meals per capita per day, rationing food intakes, reliance on food relief and sale of livestock to purchase food commodities. Although cultivation along the river banks are restricted by legal provisions, the practice is rampant in Kitui County and blamed for rapid drying up of river beds.

As a response to chronic food insecurity which has gradually eroded the household's asset base, public and private entities have introduced social protection measures in Kitui County to break the cycle of hunger and food-based emergency humanitarian aid. One such measure is the Productive Safety Net Programme (PSNP) that is designed to meet the needs of food insecure households through multi-year predictable resource transfers rather than food-based emergency assistance. The PSNP has two main components: labour intensive public works (for food or cash) and direct transfers. These measures have played a role in diversifying livelihoods and enhancing household's risk management. However, competition for labour between public works and farm activities could constrain labour intensive adaptation options if the timings for both activities overlap.

Other causes of food insecurity apart from drought include lack of farm inputs (3%) and lack of enough land (1%) (Figure 4.13).

Figure 4.13: Distribution of households by reasons for food insecurity

4.4.3 Livestock Farming

The major factors that negatively influence livestock rearing in Kitui region are inadequate pasture (59%), water scarcity (15%) and livestock diseases (14%) (Figure 4.14).

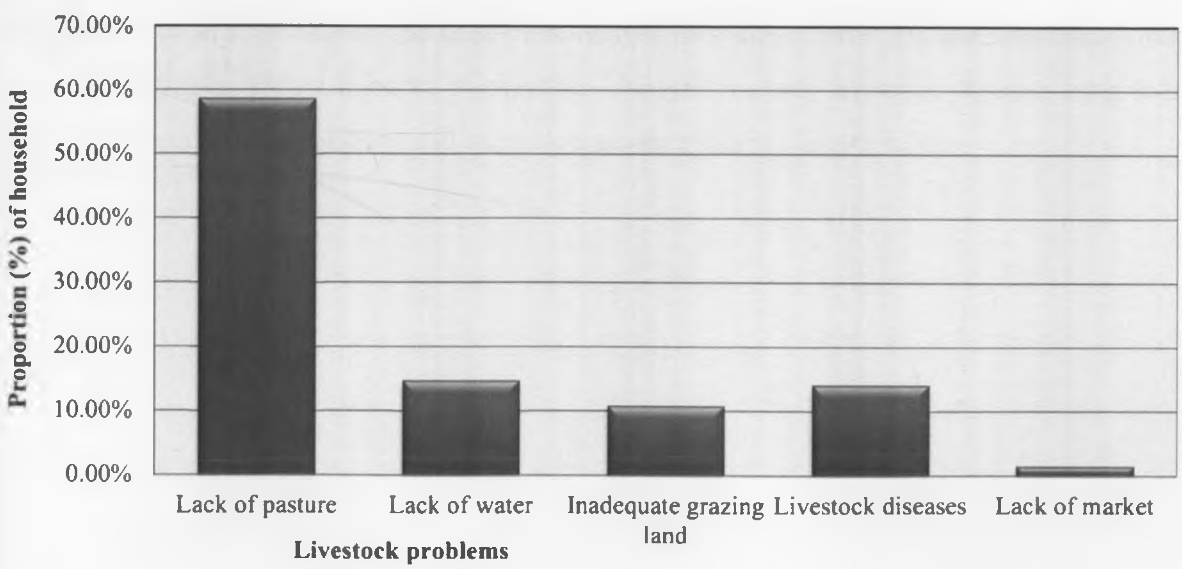


Figure 4.14: Major problems regarding livestock rearing in the region

4.5 Perception of Respondents on Climate Change

4.5.1 Main Indicators of Weather Changes

Various changes have been witnessed in weather conditions over the past 20 years. The most significant of these has been prolonged drought (54%) and unpredictable rains (36%) (Figure 4.15).

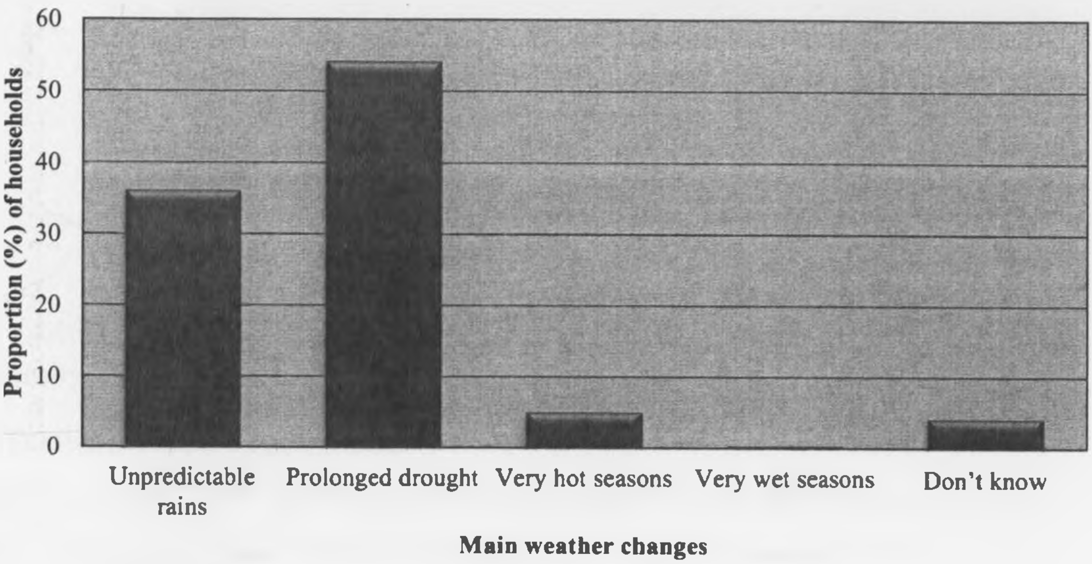


Figure 4.15: Distribution of households by main weather changes over the last 20 years

According to most respondents, the observed changes in weather have resulted into crop failure and famine (95%). Other impacts of weather changes include livestock disease outbreaks, increased human disease episodes and migration to other places (Figure 4.16).

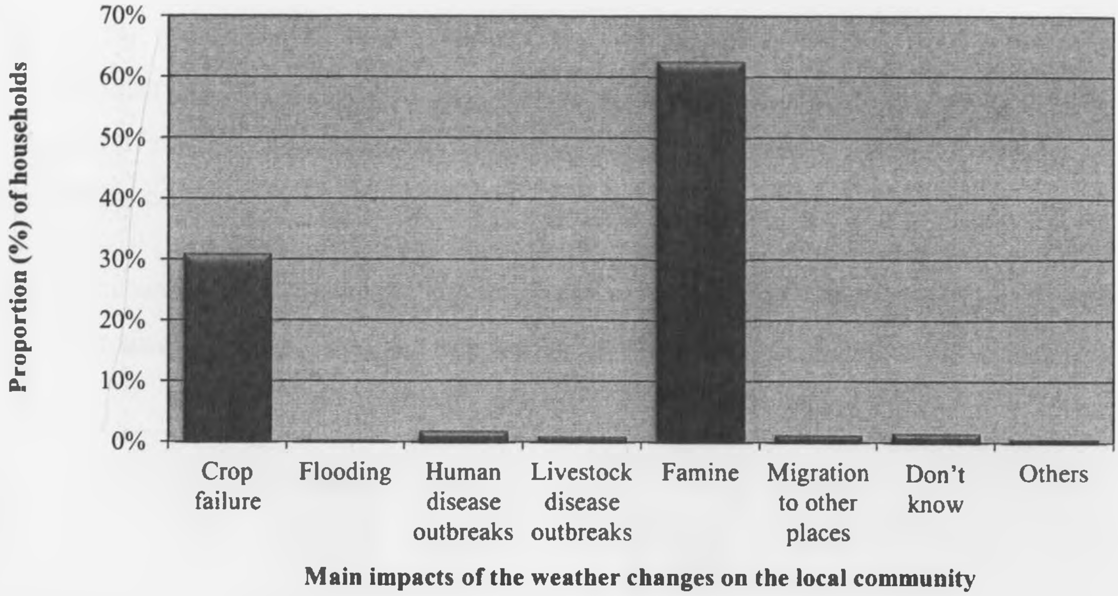


Figure 4.16: Distribution of households by main impacts of weather changes on the local community

4.5.2 Temperature and Precipitation Changes

Farmer perceptions on long-term temperature changes were divided into five categories. The results indicate that most farmers (90%) perceive the temperatures in Kitui region to be increasing. Only 6% reported the contrary (Figure 4.17).

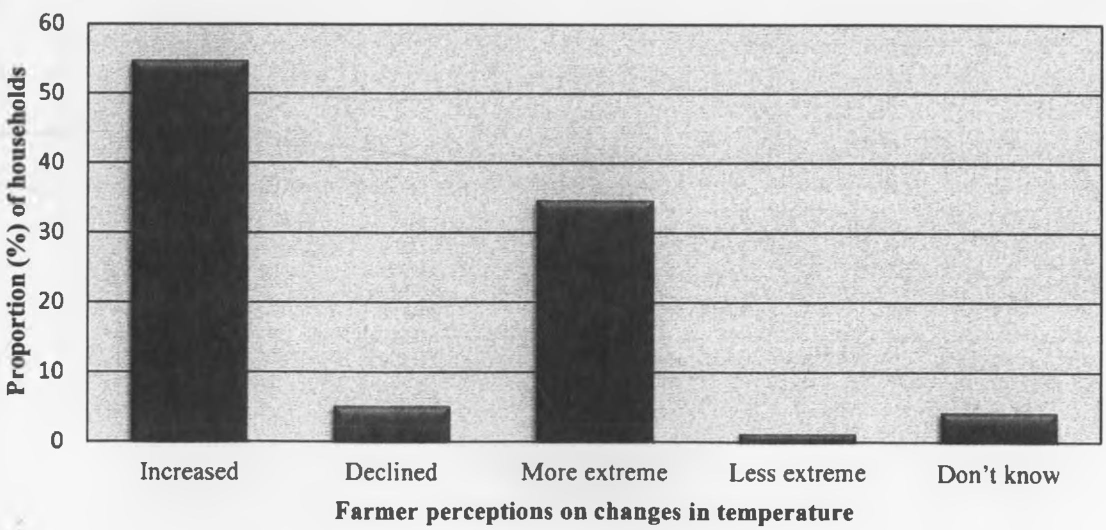


Figure 4.17: Distribution of households by farmer perceptions on changes in temperatures

The results for precipitation show a similar uniformity of opinion. In total, 96% of the respondents observed changes in rainfall patterns over the past 20 years, 85% noticed a decrease in the amount of rainfall or shorter rainy seasons, while 7% noticed a change in the timing of the rains, with rains coming either earlier or later than expected (Figure 4.18).

The perception on long-term changes in precipitation is that the region is getting drier and that there are pronounced changes in the timing of rains and frequency of droughts.

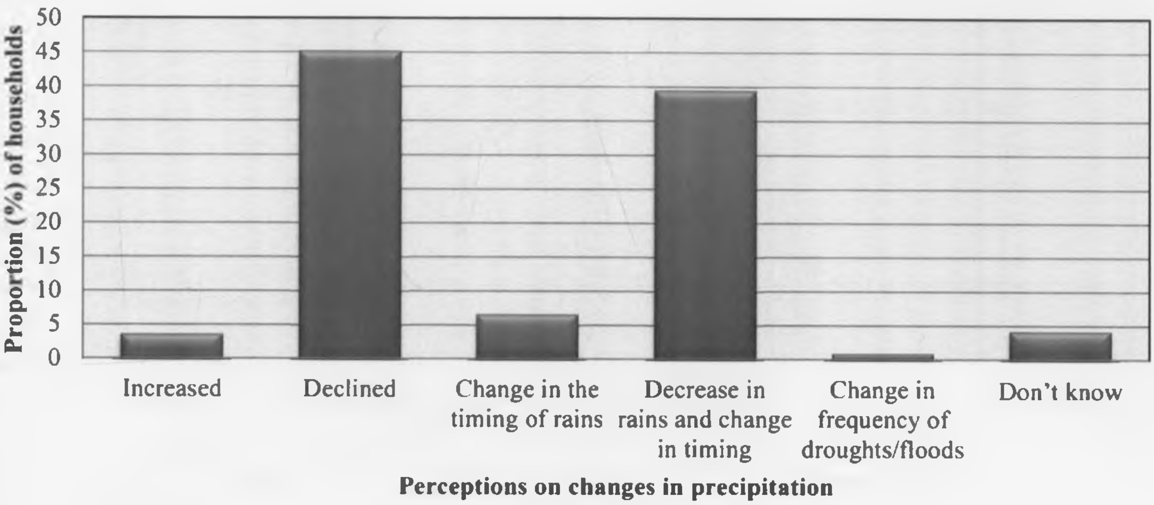


Figure 4.18: Distribution of households by farmer perceptions on changes in precipitation

4.6 Coping and Adaptation Options to Climate Change and Variability in the Study Area

Most farmers (82%) in the region have adjusted their farming practices to long-term climate change. Only 18% have not adjusted (Figure 4.19).

Figure 4.19: Distribution of households by coping measures to climate change

Eight measures were identified as farmers' responses to increased temperatures and reduced precipitation (Figure 4.20): soil conservation schemes (61%), changing crop varieties (60%), reducing the number of livestock (52%), diversification of crop types and varieties (40%), different planting dates (30%), diversification to non-farming activity (18%), water harvesting schemes (15%), and reducing the size of land under cultivation (12%). Other adaptation measures were cited by less than five percent of farmers.

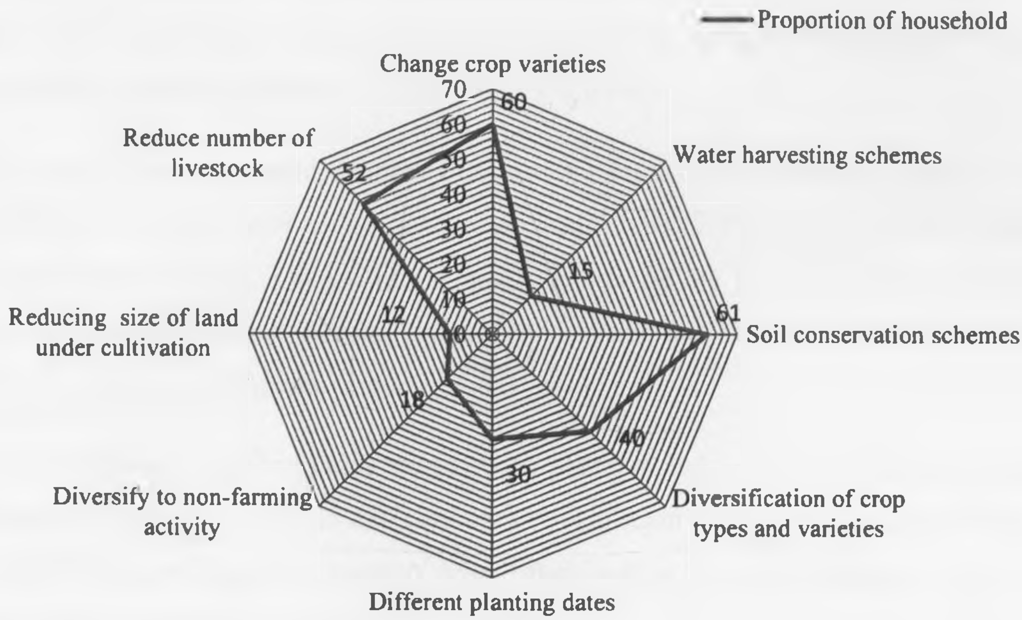


Figure 4.20: distribution of households by coping and adaptation measures

Nevertheless, taking into consideration the scope and type of coping/adaptation measures, they were classified into four measures: crop management, soil and water management, livestock management, and livelihood diversification. Crop management and soil management strategies were more adopted than water management strategies.

A significant finding that emerged from FGDs is the re-introduction of traditional cereal crops like finger millet and sorghum. In addition, the community has adopted the cultivation of early-maturing crops such as cowpeas and improved varieties of maize.

4.7 The Empirical Models and Results

4.7.1 Modelling Adaptation with the Heckman Probit Model

The estimated coefficients of the Heckman probit model are presented in Table 4.8. The coefficients of socio-economic attributes on perception and adaptation had positive and negative signs. A positive sign suggests that as levels of these attributes increase from the status quo, the probability of perceiving climate change and/or adapting to it increases. Contrastingly, a negative sign suggests that as levels of these attributes increase from status quo, the probability of perceiving, or/and adapting to climate change decreases. All estimated coefficient equations were statistically significantly different from zero at 1% level.

Age of the head of farm household, number of schooling years, household size, nearest to water sources, access to extension, and living in Mutomo and Ikutha districts influence the likelihood of perceiving climate change. On the other hand, the age of the household head, number of schooling years, nearest to water source, distance to markets, and access to extension influence the likelihood of adapting to climate variability and change.

Farmers who had more schooling years are likely to perceive and adapt to climate change. Age of the household head and access to extension have significant positive influence on adoption. Farmers who are situated close to markets where they sell or buy their produce and close to water sources are more likely to adapt to climate change.

Nearest to water sources and access to extension positively and significantly increase the likelihood of perceiving climate change. The results also show important variation in perceiving climate change across districts. Farmers in Ikutha and Mutomo districts are more likely to perceive climate change than farmers in Lower Yatta.

Table 4.8: Results of Heckman Probit model of perception and adaptation behaviour in Kitui County

Variables	Estimated coefficient selection equation: perception model	Estimated coefficient outcome equation: adaptation model
Age	**.0071*****	**.0321****
Gender	-.0123	.1064
Education	**.0198*****	**.0539****
Household size	**.0190*****	-.0013
Nearest to water source	**.0068****	**-.0647****
Distance to markets	.0020	**-.0701****
Access to extension	**.0979*****	**.3443***
Membership to social group	.0250	.0635
Farming experience	.0002	-.0064
Farm size	.0005	.0087
Mutomo dummy	**.2262 *****	.0948
Ikutha dummy	**.1298*****	.1342
Log likelihood: 12.4455		
Pro > chi2: 0.0000		
Wald chi2(11): 8676.27		
Athrho: .7079***		
Rho: .6094		
Total observations: 310		
Censored observations: 52		

Note: *** significant at 1% level ** significant at 5% level * significant at 10% level

Educational attainment, age of the head of the farm household, household size, and access to extension have significant and positive marginal effect on perceiving climate change and variability. However, distance to market had significant and negative marginal effect on perception.

The marginal effect of educational attainment on the probability of adapting to climate change is positive. In contrast, the marginal effects of distances to market and nearest to water points are significant and negative. The marginal effect is the percentage change in probability of perception or adoption associated with a unit increase of the variable from the mean value.

4.7.2 Modelling Adaptation with the Multivariate Biprobit Model

Results from the multivariate biprobit model of determinants of adaptation measures are presented in Table 4.9. The choice set in the MVBP model included eight different adaptation options: crop varieties, water harvesting technologies, crop diversification, different planting dates, reducing the size of land under cultivation, reducing the size of livestock, diversification to non-farming activities, and soil conservation practices.

The results of the correlation coefficients of the error terms are significant for any pairs of equations indicating that they are correlated. The results on correlation coefficients of the error terms indicate that there are complementarities (positive correlation) between different adaptation options being used by farmers. The results supports the assumption of interdependence between different adaptation options which may be due to complementarity in the different adaptation options and also from omitted household-specific and other factors that affect uptake of all the adaptation options.

The likelihood ratio test based on the log-likelihood values indicate significant joint correlations (probability > χ^2 = 0.0002). This supports the use of a MVBP model that considers the use of different adaptation options.

Table 4.9: Results of multivariate biprobit analysis of factors influencing uptake of eight adaptations choices

Variables	Crop varieties	Water harvesting schemes	Crop diversification	Different planting dates	Reducing the size of land	Reducing size of livestock	Diversify to non-farming	Soil conservation schemes
Sex	0.056	0.050	0.145	-0.058	0.133	-0.067	0.029	0.018
Age	-0.009	-0.004	-0.010	-0.009	-0.006	0.009	-0.007	0.008
Education	-0.002	**0.086*** **	0.027	0.007	0.034	**0.054*** **	-0.026	0.001
Household size	-0.033	0.027	-0.045	0.015	**-0.076***	-0.013	0.041	0.001
Social group	0.177	0.058	-0.037	-0.104	**0.461***	0.095	**0.318***	0.225
Access to water	**-0.049****	-0.034	-0.008	0.002	-0.031	-0.030	-0.027	-0.031
Farm size	**0.009***	0.003	0.004	0.003	-0.001	-0.002	-0.004	0.002
Farming experience	-0.003	0.004	0.002	0.012	0.000	0.007	0.002	-0.010
Distance to market	-0.023	0.013	-0.013	-0.018	0.000	0.000	**-0.035***	-0.012
Access to extension	0.012	-0.117	**0.296***	0.209	0.346	0.178	-0.175	-0.153
Mutomo dummy	-0.133	0.078	**-0.823*****	0.079	**-0.613****	**-0.560*****	**-0.684****	**-0.791*****
Ikutha dummy	-0.204	-0.131	**-0.473****	-0.120	**-0.475***	**-0.429****	**-0.646*****	-0.223
Constant	**1.127***	**-1.979*****	0.493	-0.519	-0.857	-0.894	0.627	0.627

No. of observations = 310, Wald chi(96)=152.80, Pro>chi2 = 0.0002, Log likelihood = -1309.23

Note: *** significant at 1% level ** significant at 5% level * significant at 10% level

The results suggest that socio-economic, institutional and farm characteristics are significant in influencing household adoption decisions. The MVBP model shows that farmers who had more years of schooling will probably adopt water harvesting technologies. Similarly, they are risk averse and therefore more likely to reduce the size of livestock. The household size of farmers has a positive coefficient on the likelihood to increase the size of land under cultivation.

Large farm size is significant and positively correlated with planting different crop varieties. Similarly, access to water increases the likelihood of adopting crop varieties. Access to extension service significantly increases the likelihood of taking up diversification of crop types and varieties. On the other hand, Membership to social group increases the likelihood of increasing the size of land under farming and diversification to non-farming activities. Similarly, proximity to market increases the probability of diversifying livelihoods.

Adoption also varies by districts. The negative coefficients for Mutomo and Ikutha dummies for diversification of crop types, reducing the size of land under cultivation, reducing the size of livestock and diversification to non-farming activities imply a lower probability of adoption if a farm household is located in these districts, rather than in Lower Yatta district (reference district). Similarly, farmers in Mutomo are less likely to adopt soil conservation practices. These results reflect unobservable spatial differences.

4.8 Constraints to Adaptation

More than 56% of farmers cited lack of financial capital and poverty as the main constraints to adaptation (Figure 4.21). Despite perceiving a decrease in the amount of rainfall, only 9% of the respondents perceived lack of access to water to be a barrier to adaptation. Likewise, 3% believed they lack man-power to carry out labour intensive adaptation strategies. However, 28% felt that they lacked education, information and training about appropriate adaptations. Poor health was also cited as significant barrier to adaptation.

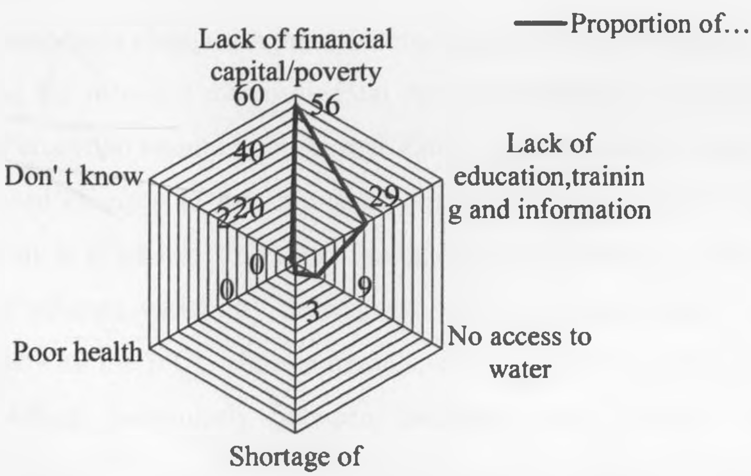


Figure 4.21: Distribution of households by constraints to adaptation

CHAPTER 5: DISCUSSIONS

Three key findings are drawn from this study. It has shown a steady decline in both seasonal and annual rainfall in the region, and concomitant decline in maize crop yield. Second, farmer perceptions of climate change were consistent with recorded meteorological data. Third, educational attainment, household size, membership to social and economic groups, access to extension service and access to water, farm size and Proximity to market are key factors influencing adaptation uptake.

An important finding of this study is the attribution of climate variability and change to crop production. Maize crop yield between 1997 and 2007 declined from 10800 – 360 tonnes. During the same period, rainfall had declined from 1062 to 318 mm. This decline in maize production is attributable to rains ($y = -34.272x + 691.82$), an indicator of changing climate. Similar studies in Kenya (Njiru et al., 2010) and South Africa (Kori, Gondo & Madilonga, 2012) showed declining trends in both seasonal and annual rainfalls and their negative impacts on crop yields and acreage of land under cultivation, respectively. This finding is also in concurrence with the regional climate models that anticipate rainfall declines across eastern Africa during the long rains (Seitz & Nyangena, 2009), with negative impacts on rain-fed agriculture (IPCC, 2007, 2012; FAO, 2008, 2010)

Farmer perceptions of long-term changes in precipitation were consistent with rainfall data. This was done by comparing the recorded meteorological data with climate change as perceived by farmers in the region. Perception results indicate that Kitui region is getting hotter and drier and that there are pronounced changes in the timing of rains and frequency of droughts. Similar studies in India (Vedwan & Rhoades, 2001) and South Africa (Gbetibouo, 2009) revealed that farmers' perceptions of climate variability correspond with the climate data. However, these observations are at odds with the IPCC climate models, which anticipate precipitation increases in parts of Eastern Africa, particularly between December and February. The declining continental rainfall in Eastern Africa is linked to the anthropogenic warming of the central Indian Ocean that disrupts onshore moisture transports (Cane, et al., 1986; Funk, et al, 2008).

While there is heterogeneity with regard to factors that influence uptake of eight adaptation choices, this study underscore the importance of educational attainment, membership to social and economic group, household size, access to extension service, access to water, farm size and proximity to markets on household adoption decisions. Household and farm characteristics and institutional factors had differential influence on uptake of adaptation options. Farmers who had twelve years or more of schooling were likely to perceive and adapt to climate change. Similar studies in 11 African countries (Maddison, 2006) as well as, Burkina Faso and Guinea (Adesina & Forson, 1995) found that higher levels of education influence access to information and knowledge, which in effect enhances adoption of agricultural technologies.

The household size of farmers has a positive coefficient on the likelihood to increase the size of land under cultivation. Household size as a proxy to labour availability is associated with acreage of land under cultivation. This implies that large household is more likely to adopt labour-intensive technologies. In western Kenya (Marenya & Barrett, 2007) and Uganda (Nkonya *et al.*, 2008), it was observed that family rather than hired labour provided most farm operations. Therefore, large households are more likely to overcome labour contraints and adopt new farming practices.

Membership to social and economic groups influences the adoption of farm management practices and diversification of livelihoods. This suggests that government support to social groups is crucial in enhancing livelihood diversification and adoption of sustainable agricultural technologies. Similar studies in Tanzania (Kessie et al., 2012) and Kenya (Ochieng' et al., 2012) showed that social groups could pull resources together for their individual benefits, and access information from extension NGOs and government. As a result, they can help their members to access farm inputs on schedule, overcome credit constraints, lobby for good policies, and bargain for better prices.

Improved farmer access to extension service increases the probability of perceiving and adapting to climate change. Studies in Nigeria (Gbegeh & Akubuilo, 2012) and several other African countries (Maddison, 2006) showed that farmers who have access to extension services are more likely to be aware of changing climatic conditions, and have knowledge of the various management practices that they can use to adapt to changes in climatic conditions. Promoting awareness to changes in climatic conditions would therefore have greater impact in enhancing adoption. This would be attained through appropriate communication pathway available to farmers such as extension service.

Access to water reduces the likelihood of adopting crop varieties. This suggests that farmers who are situated close to water sources are less likely to adopt water efficient technologies, and will therefore grow different crop varieties regardless of their individual water needs. A similar study in South Africa (Nhemachena & Hassan, 2007) showed that access to water increases the likelihood of adopting farm management practices, in particular, growing crop varieties that suit the prevailing soil moisture content.

Large farm size increases the likelihood of adopting different crop varieties. Owners of large-sized farms are relatively wealthy and can try out new farming practices. This finding resonates with a study by Rogers (1995) who concluded that earlier 'adopters' had large sizes of land. Proximity to market increases the likelihood of adopting non-farming activities. This implies that nearness to market serves as an incentive to farmers who would like to diversify their livelihoods. Similar study in eleven African countries (Maddison, 2006) show that markets serve as a means of exchanging information about crop and livestock management with other farmers. While not an end itself, exchange of information will also enhance opportunities for livelihood diversification.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

- Farmers in Kitui County are exposed to climate variability at intra-and inter-annual and decadal time scale. The increasing climate variability and reduction in precipitation have serious implications for food production and availability in Kitui County.
- Climate data and farmer perception indicate that farmers are aware that the region is getting dry with increased frequency of droughts and change in the timings of rains. Older farmers and those with access to extension services were likely to perceive changes in climate. Nonetheless, the older farmers are less likely to respond to the perception of a changed climate.
- Most farmers have embraced at least one adaptation strategy, which are mainly influenced by perceptions and baseline climate. However, the fact that most farmers have taken up adaptation measures to their agricultural practices does not necessarily mean that those adaptations are appropriate to local contexts.
- The findings of this study resonate with the literature on adoption of agricultural technologies. The number of schooling years, household size, access to water, access to extension services, membership to social group, and proximity to the market were found to determine the extent to which individual farmers respond to the perception of a changed climate. However, the most important finding for this study was that whereas it is age of the farmer and household sizes that determine whether or not farmers perceive climate variability and change, it is educational attainment and membership to social group that largely determines whether or not they adapt to it.
- While farmers in Kitui County have, for a long time, developed local strategies to cope with erratic environmental shocks, increased variability and extreme weather events have exceeded the present coping range and adaptive capacity. Enhancing adaptive capacity is therefore indispensable to strengthening resilience and reducing vulnerability. The starting point entails complementing autonomous adaptation strategies with micro-level policy responses. Formulating and implementing such policies require devolution of authority and community participation to ensure that they empower the local farmers and elevate their role in policy formulation.

6.2 Recommendations

Although most farmers in Kitui demonstrated strong self-interest in adapting, numerous obstacles constrain their options. The following Interventions are needed to create conditions that will enable the local community and individual households to take up appropriate adaptation options:

- Develop and implement integrated natural resource management in arid and semi-arid lands (ASALs). This calls for harmonisation of key conflicting policies in key sectors such as water, land, tourism and wildlife, mining, energy, agriculture, and pastoralism to enhance cross and inter-sectoral linkages.
- Enhance opportunities for small-scale irrigation, and water harvesting. However, irrigation investment should guarantee high water use efficiency with emphasis on water pricing, besides building farm level managerial capacity. This will require revision of existing policies and institutional frameworks in water and agricultural sectors.
- Promote formation of local rural institutions and farmer groups, and create more opportunities for livelihood diversification.
- Encourage transition to climate-smart agriculture that take an agro-ecological approach, rely less on natural rainfall, invest in long-term soil health, and use fewer external inputs, but guarantee food security.
- Improve the availability and quality of meteorological monitoring data, enhance climate modelling with robust articulation of uncertainties, and promote farmer awareness to the impacts of climate change through extension services.
- Review farmer extension systems and design farm management adoption programmes based on the socio-economic characteristics, such as years of schooling and membership to social groups of smallholder farmers.

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LIST OF APPENDICES

Appendix 1: Household Questionnaire

IDENTIFICATION
Village/S/Loc./Location/Division/County..
HOUSEHOLD NUMBER ....|___||___||___|

N°	QUESTIONS	ANSWERS
	A. SOCIO-DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS	
101	**Record sex of the respondent**	01 = Male 02 = Female |___||___|
102	How old are you? **Record age in years**	Record number of years 99 = Don't Know |___|___|
103	How long have you lived in this community?	........................Years, ...Months
104	What is the highest level of schooling you have attained?	00 = None 01= Some primary education 02 = Completed Primary 03 = Secondary |___||___| 04 = College 05 = University 97=Other(specify)--------------------
105	What is your main source of income? ***(Only one answer is possible. Record the principal income sector.)***	00 = None 01 = Crop farming 02 = Business 03 = Pastoralism 04 = Salary |___|___| 05 = Wages 06 = Remittance 97 = Other (Specify) ....

N°	QUESTIONS	ANSWERS
106	Indicate what type of housing you have?	01 = Mud walled grass thatched 02 = Semi permanent with iron sheets 03 = Stone walled (permanent) [__][__] 97 = Others (specify)..
107	Do you have access to electricity?	01 = Yes 02 = No [__][__]
108	What is your main fuel for cooking in your HH?	00 = None 01 = Firewood 02 = Charcoal [__][__] 03 = Kerosene 04 = Residues (specify) 97 = Other materials (specify)........................
109	What is your marital status?	01 = Single 02 = Married 03 = Divorced/Separated [__][__] 04 = Widow/ Widower 98 = No answer 99 = Don't know
110	If male, number of wives	**RECORD EXACT NUMBER** [__][__]
111	Do you have any child/children?	01 = yes 02 = No [__][__]
112	If YES above, how many children do you have?	**RECORD EXACT NUMBER** [__][__]
113	How many of the above children are in school?	**RECORD ACTUAL NUMBER** [__][__]
114	Are there any of your children who are of school going age and are currently not attending school?	01 = yes 02 = no [__][__]
115	If YES above, what are the reasons that they are not attending school?	01=Lack of fees 02=Lack of/Inadequate schools 03=Refused to go to school 04=Married [__][__] 05=working 97=Others (specify)..
116	Apart from your children, how many more people are you staying with in your household	01=none 02=one to three [__][__] 03=four and above

<table>
<tr><th>N°</th><th>QUESTIONS</th><th>ANSWERS</th></tr>
<tr><td>11</td><td>Do you belong to any social group?</td><td>01 = yes
02 = no |__||__|</td></tr>
<tr><td>11</td><td>If yes, give a list of groups you belong to.</td><td>…………………………………………………
…………………………………………………
…………………………………………………
…………………………………………………
………………………………………………</td></tr>
<tr><td>11</td><td>How far is your nearest water source?</td><td>01=Less than 1 km
02=1 – 3 km |__||__|
03= 4 – 5 km
04 = Over 5 km</td></tr>
<tr><td>12</td><td>What problems do you experience in assessing water?</td><td>01=Long distance
02=Dirty water |__||__|
03= Scarcity of water
04 = Conflict with neighbouring communities
99 = Don't know</td></tr>
<tr><td colspan="3">B. LAND OWNERSHIP AND UTILIZATION</td></tr>
<tr><td>12</td><td>What is the size of your land?</td><td>01 = Less than one acre
02 = 1 to 3 acres
03 = 4 to 5 Acres
04 = 6 to 10 Acres |__||__|
05 = Over 10 acres
99 = Don't know</td></tr>
<tr><td>12</td><td>What is the total area under cultivation?</td><td>RECORD ACTUAL IN ACRES
|__||__|</td></tr>
<tr><td>12</td><td>What is the total area of land under pasture?</td><td>RECORD ACTUAL IN ACRES
|__||__|</td></tr>
<tr><td>12</td><td>What is the total area of land under tree cover?</td><td>RECORD ACTUAL IN ACRES |__||__|</td></tr>
<tr><td>12</td><td>What food crops do you grow?</td><td>01 = Maize
02 = Beans
03 = Millet
04 = Cassava |__||__|
97 = Others
(Specify)…………………………………………</td></tr>
<tr><td>12</td><td>What is the location of your land?</td><td>01 = Uplands/ slopes
02 = Lowlands
03 = Plains
04 = River valley |__||__|</td></tr>
<tr><td>12</td><td>Farmer's own perception of the fertility level of his land</td><td>01 = Very fertile
02 = Fertile |__||__|
03 = Infertile
99 = Don't know</td></tr>
</table>

N°	QUESTIONS	ANSWERS
12	How long have you been a farmer?	01 = Less than 5 years 02 = 6 – 10 years 03 = 11- 20 years 04 = Over 20 years
12	What is the type of land ownership?	01 = Private property with title deed 02 = Communal land 03 = Ancestral land 04 = Leasehold 97 = Other (specify)...
13	Who makes decision over land management?	01 = Head of household 02 = The entire family 97 = Other (specify)
13	What is the distance from nearest market?	01 = Less than one kilometer 02 = 1 – 10 Kilometres 03 = Over 10 kilometres
13	What is the main means of transport for farm products to the market?	01 = Lorry 02 = Bus 03 = Matatu 04 = Cart (Mkokoteni) 05 = Donkey 97 = Other (Specify) ....
132.	What are sources of extension services	00 = None 01 = Government 02 = Private 03 = NGOs 97 = Other (Specify)
133.	What is the frequency of extension services	01 = Weekly 02 = monthly
134.	What is your mean monthly household income from employment	01 = up to 10,000 Ksh 02 = 10,001 - 30,000 03 = 30,001 - 50,000 04 = over 50,000
D. FOOD SECURITY		
135.	Does the household experience shortages of main food items?	01 = Yes 02 = No
136.	If **no**, what crops do you sometimes produce as surplus for sale? (Multiple responses allowed)	01 = Maize 02 = Beans 03 = Millet 04 = Cassava 05 = Others (Specify)................................

137.	If yes, how many food deficient months do you experience in a year?	01 = Less than 3 months 02 = 4 – 5 months 03 = Over 5 months |__||__|
138.	If yes, what are the reasons for food shortages? (Multiple responses allowed)	01 = Drought 02 = Floods 03 = Lack of farm inputs 04 = Land not enough 97 = Others (specify)............................ |__||__|
139.	If yes, how do you cope with food shortage?	01 = Buy food (list the food items bought) 02 = Eat an alternative food (List) 03 = Beg assistance from relatives, friends or neighbours. 04 = Beg food relief from government. 97 = Others (specify)............................ |__||__|

E. HOUSEHOLD ASSETS

140. Please indicate which of the following assets that you own

Asset	**Number**
Farm equipments	
Tractor	
Oxen plough	
Wheelbarrow	
Water pump	
Pangas/Jembe	
Other assets	
Bicycle	
Motor bike	
Cart (Mkokoteni)	
Water tank	
Motor vehicle	
Radio	
TV set	
Pressure lamp	
Charcoal stove	
Livestock Type and Number	
Local cattle	
Improved cattle	
Local goats	
Improved goats	
Sheep	
Local poultry	
Improved poultry	

Donkeys		
Others (specify)		

141.	What is the major problem regarding livestock in your community	01 = Lack pasture 02 = Lack of water 03 = Inadequate grazing land 04 = Livestock diseases 05 = Lack of market 97 = Others (specify).......................................
F. CLIMATE CHANGE AND VARIABILITY		
142.	What significant changes in weather have you observed in your community over the last 20 years?	01 = Unpredictable rains 02 = Prolonged drought 03 = Very hot seasons 04 = Very wet seasons 99 = Don't know 97 = Others (specify).......................................
143.	What is the main impact of these changes on the local community?	01 = Crop failure 02 = Flooding 03 = Human disease outbreaks 04 = Livestock disease outbreak 05 = Famine 06 = Migration to other places 99 = Don't know 97 = Others (specify).......................................
144.	What changes would you associate with climate change on each of the following: 1. crop production, 2. livestock production, 3. income generation, 4. human health, 5. water sources?	1. Crop production ....
145.		2. Livestock production ....
		3. Income generation ....

		4. Human health …………………………………………… …………………………………………… …………………………………………… ……………………………………
		5. Water sources …………………………………………… …………………………………………… …………………………………………… ……………………………………………
146.	Do you perceive climate variability and change?	01 = yes 02 = No |__||__|
147.	If yes, what has happened to the number of hot days over the last 20 years?	01 = Increased 02 = Declined 03 = More extreme 04 =Less extreme |__||__|
148.	If yes, what has happened to the number of rainfall days over the last 20 years?	01 = Increased 02 = Declined 03 = Change in the timing of rains 04 =Decrease in rains and change in timing 05 = Change in frequency of droughts/floods |__||__|
149.	Have you made any adjustment in your farming practices to climate variability and change?	01 = Yes 02 = No |__||__|

150.	What adjustments have you made in your farming practices to these long-term shifts in temperature and rainfall? Tick the adjustments made. (Multiple responses allowed)	01 = Change crop variety	
		02 = Build water harvesting schemes	
		03 = Implement soil conservation schemes	
		04 = Diversification of crop types and varieties	
		05 = Diversification of livestock types and varieties	
		06 = Changing planting dates	
		07 = Changing size of land under cultivation	
		08 = Irrigation	
		09 = Reduce number of livestock	
		10 = Diversify from farming to non-farming activity	

		97 = Others (specify)................................ ....
151.	List the main constraints to adaptation measures	01 = Lack of capital 02 = Lack of information 03 = Shortage of labour 04 = Lack of access to water 05 = Poor health 97 = Others (specify).. |__||__|
152.	Are there institutions/organisations your community has worked with to address the effects of climate change on livelihood?	01 = Yes 02 = No |__||__|
153.	If, yes please indicate what type of institutions/organisations they were?	01 = NGOs 02 = Government ministry 03 = Private sector 04 =An individual 97 = Others (specify) 99 = Don't know |__||__|
THANK YOU FOR YOUR COOPERATION		

Appendix 2: Informed Consent

(The following statement must be read to every respondent)

CONSENT FORM

Hello Sir/Madam,

My name is.......................... I am a graduate student of Environmental Policy at the University of Nairobi doing a research on perceptions and adaptation measures of small scale farmers to climate change in Kitui County, Kenya. In order to meet this objective, it is important to obtain information from the Kitui residents such as you.

This information is being collected for academic purposes only, and there are no personal benefits or risks to your participation. It is possible that some of the questions asked, are of a sensitive nature, but please note that your name will not be recorded in the questionnaire, and any details related to your privacy will be kept confidential. The interview will take approximately 30 minutes, but with your cooperation it can be done quicker. For more information about this study, please contact the researcher on ..., or email...

May I have your permission to undertake this interview?

Yes ☐ (proceed with interview)

No ☐ (thank the person and look for next respondent).