EVALUATION OF FARMERS' VULNERABILITY TO CLIMATE VARIABILITY AND EXTREME EVENTS IN SELECTED AGRO-ECOLOGICAL ZONES IN KITUI COUNTY, KENYA

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CLIMATE CHANGE AND AGRO-FORESTRY OF SOUTH EASTERN KENYA UNIVERSITY.

2020

DECLARATION

I understand that plagiarism is an offense and I therefore declare that this thesis is my original work and has not been presented in any other institution for any other award.

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ACKNOWLEDGEMENT

I would like to express my sincere gratitude to Dr. Charles Ndung'u, and Dr. Felista Muriu-Ng'ang'a, Department of Environmental Science and Land Resource Management, South Eastern Kenya University for their advice, guidance, supervision and tireless efforts towards the success and quality of this thesis. I also acknowledge the Climate Smart Agriculture Project for sponsoring the field work.

I owe indebtedness to all my course lecturers in the school of Environment, water and Natural Resources for their encouragement and advice during my study period.

I also express my gratitude to my course-mate Modvine Koreeny for her support, criticism, advice and encouragement which helped improve the quality of this research work. Further, I would like to appreciate my dear friend, Peter Mbuvi, my sisters Maryanne and Anne for their sincere love, support and encouragement during the entire study period. God bless you abundantly. Special thanks are due to my father Joseph Kamau and my mother, the late Agnes Wambui.

Finally, I thank the Almighty God for strength, life and wisdom that enabled me to sail through the waves of this research work.

DEDICATION

I would like to dedicate this research work to my cherished parents, Joseph Kamau and the late Agnes Kamau and my siblings for their love, support and encouragement during the entire study period. May the Almighty God bless you.

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ABBREVIATIONS AND ACRONYMS

AGRA	Alliance for Green Revolution in Africa
ASALs	Arid and Semi-Arid Lands
CSA	Climate Smart Agriculture
FACE	Free Air Carbon Enrichment
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GHG	Green-House Gases
GoK	Government of Kenya
IPCC	Inter-governmental Panel on Climate Change
ISDR	International measure for disaster reduction
KNMI	Kenya National Meteorological Institute
NGOs	Non-Governmental Organizations
SST	Sea Surface Temperature
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization
IAASTD	International Assessment of Agricultural knowledge, Science and Technology for Development

DEFINITION OF TERMS

Climate extreme events: Refers to unexpected, unusual, unpredictable, severe and or unseasonal weather events observed over years at the extremes of historical distribution (IPCC, 2014).

Resilience: described as the capacity of a system, community, household or individual to prevent, mitigate, cope and recover from shocks and risks at a specific time.

Climate vulnerability: Defined as a function of the magnitude, character and rate of climate variation to which a system is exposed, its sensitivity and adaptive capacity (Ndung'u *et al*., 2015).

Exposure: Refers to the degree of a perturbation, stress, hazard or shock upon a particular unit of analysis, which causes a significant transformation or changes to a system (Gbetibouo *et al*., 2009).

Sensitivity: Is the degree to which a system is affected or modified by climate change without accounting for adaptation (IPCC, 2014)

Adaptive capacity: Is the ability of a system to adjust to climate change (including climate variability and extreme events), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (Luni *et al*., 2012).

Abstract

Climate variability and extreme events are some of the most pressing environmental challenges occurring in the contemporary world. Farming communities in Sub-Saharan Africa, particularly in Kenya are more vulnerable to climate variability and extreme events due to high dependence on weather patterns in their farming activities. There is little understanding of the vulnerability to climate variability and extreme events among farmers in Kitui County based on the agro-ecological zones. This study evaluated farmers' vulnerability to climate variability and extremes and adaptation strategies adopted in selected parts of Kitui County using data collected from 341 households in Yuku, Kaveta, Kauwi and Kasaini sub-locations which represented arid, semi-humid, semi-arid and transitional zone from semi-humid to semi-arid agro-ecological zones respectively. Purposive sampling method was applied in identifying the sub-locations of study while proportionate and systematic sampling were used to select the households which formed the units of analysis. Analysis on vulnerability was based on indices constructed from carefully selected indicators for exposure, sensitivity, and adaptive capacity. The indicators were weighted using Equal Weight Analysis. Vulnerability indices indicated that Yuku sub-location was the most vulnerable to climate variability and extreme events (1.487) followed by Kauwi (0.214), Kasaini (0.085) and Kaveta sub-location (-0.530). Further, the results indicated that farmers in the study areas had adopted multiple adaptation strategies in response to climate variability and extreme events. Results of the logistic regression analysis showed that gender, education level, farming experience and age significantly ($p<0.05$) influenced adoption of adaptation strategies to climate variability and extreme events in the study areas. Policy measures and development efforts should be focused towards addressing the factors that influence adoption of adaptation strategies while improving the adaptive capacity of farming households in Kitui County.

CHAPTER ONE

1.0 Introduction

1.1 Background Information

Natural climate variability and extreme events have been identified as major challenges facing human livelihoods globally. Anthropogenic climate change has added a complex new dimension to this challenge. Studies have shown that natural climatic variability, compounded with human induced climate change will adversely affect millions of livelihoods around the world (IPCC, 2007; LVBC, 2011). The World Meteorological Organization distinguishes climate variability from climate change with the former referring to variations in the mean state and other statistics of climate on temporal and spatial scales beyond individual weather events for years (usually up to three decades) as a result of natural processes while climate change is associated with anthropogenic activities such as land use change leading to climatic variations for longer durations often centuries (WMO, 2015).

As global average temperature increases, there will be considerable differences in temperature rise between land and sea and between high and low latitudes. Precipitation is likely to increase in high latitudes, while decreases are expected in most of the tropical and subtropical regions (IPCC, 2007). Worldwide, the livelihoods of 2.5 billion people depend on agriculture (FAO-United Nations, 2016). These small-scale farmers, herders, beekeepers, fishers and forest-dependent communities generate more than half of the global agricultural production and are particularly at risk from climate variability and extreme events that destroy harvests, equipment, supplies, livestock, seeds, crops and stored food.

In Africa, climate is warmer than it was 100 years ago and model-based predictions of future GHG induced climate change for the continent clearly suggest that this warming will continue and, in most scenarios, accelerate (Christensen *et al*., 2007). Observational records by Hulme *et al*. (2010) show that during the 20th century the continent of Africa has been warming at a rate of about 0.05°C per decade. Rural households in Sub Sahara Africa (SSA), predominantly those in arid and semi-arid regions are likely to be more exposed and vulnerable to impacts of climate variability and extreme events, a situation aggravated by limited knowledge regarding the implementation and effectiveness of current measures in reducing exposure and vulnerability (Spear *et al*., 2015). In addition, researchers have observed an increase rainfall pattern diversity over recent decades in Eastern Africa, where the average rainfall has increased in the northeastern parts (Ethiopia, Somalia, Kenya and northern Uganda) with opposite conditions in the southwestern parts (Tanzania, southern parts of the Democratic Republic of the Congo and southwestern Uganda) (Solomon, Qin *et al*., 2007).

However, it has been noted that an increase in rainfall does not necessarily lead to an increase in agricultural production, as temperature rising might have a significantly negative impact on water availability by increasing evapo-transpiration and exacerbating drought conditions (Herrero *et al.,* 2010).While it is generally accepted that poor and marginalized communities at lower latitudes are particularly exposed and vulnerable to climate variability, non-climatic pressures can mean that developed nations like Norway are also vulnerable to climate variability and extreme events (IPCC 2014). Case in point, Keskitalo *et al*. (2010) states that despite developed countries like Norway scoring high on adaptive capacity determinants such as wealth, technology, infrastructure, institutions, information and skills, such do not fully consider the contextual vulnerability dimensions of advanced industrial states.

Kenya has a land mass of approximately 582,350 km^2. Only 20% of this land is arable while the remaining 80% consists of arid and semi-arid land (ASALs; GoK, 2010). In Kenya, the impact of climate change has been more pronounced in the (ASALs) which supports 25% of the country's total human population that relies on nearly 75% livestock and crop production. The agricultural sector is a key contributor to Kenya's economic growth. The sector is estimated to contribute at least 25% of the country's GDP (Government of Kenya, 2005). The productivity of this sector has conversely been compromised by the effects of climate change and variability. In recent years, Eastern Africa (Kenya included), has been known to be prone to climate variability. Anomalous strong rainfall events seem to have increased (Van Oldenborgh *et al*., 2008). The temperature in this region has also been increasing considerably due to the changing climate. The situation exacerbated by increasing climate induced extreme events such as floods, droughts, pests, diseases among others which have resulted in a reduction in the economic activities practiced in such regions (Zoellick, 2009).

Kitui County is one of the semi-arid counties in Kenya. A large part of the county receives erratic and unreliable rainfall with most of the areas being generally hot and dry leading to high rate of evaporation (Khisa *et al*., 2014). The county has been experiencing a reduction in food production because of its vulnerability to changing and erratic rainfall pattern which has adversely affected food production. Variations in climatic conditions experienced in the county are thought to be responsible for the changes in food production. Farmers particularly, have been and continue to be vulnerable to climate variability and extreme events though some of the framers are not aware of the variations that have taken place in the climate and how these has affected agricultural production (Khisa *et al*., 2014).

According to Lobell and Burke (2010), a large majority of the world's poor continue to live in rural areas and depend on agriculture for their livelihoods. Given that agriculture everywhere remains dependent on weather, they say that changes in climate have the ability to disproportionally affect these poor populations' livelihoods. The negative effects of extreme weather conditions are heavily felt on agricultural activities which are dictated by the climatic conditions of a place. The performance of agriculture in Kenya has been declining with many regions reporting decrease in yields annually. Various factors have been cited to be the causes of poor agricultural productivity in the country. These include reduced fertilizer usage, land fragmentation, land degradation and climate variability among others (Jones *et al*., 2010).

Kitui County, like other arid and semi-arid regions is experiencing the effects of climate variability particularly in the agricultural sector. This in turn affects the livelihood of most of the county residents who greatly depend on rain-fed agriculture. FAO believes that the resilience of agricultural livelihoods is essential in making sustainable development a reality by ensuring that agriculture and food systems are productive and risk sensitive, in order to feed present and future generations, given that three-quarters of the world's poor are farmers (FAO, 2016). Therefore, measures aimed at climate adaptation in the county with a focus to increase resilience and adaptive capacity of livelihoods to climate variability and extreme events are urgent. Based on this background, this study sought to assess household level vulnerability of farmers to climate variability and extremes in arid, semi-arid and semi-humid agro-ecological zones of Kitui County.

1.2 Problem statement

The Intergovernmental Panel on Climate Change (IPCC, 2007) identified Africa among the continents which are most vulnerable to climate variability because of myriad projected impacts, numerous stresses, low risk preparedness and low adaptive capacity. Climate variability affects weather patterns and seasonal shifts which come with severe repercussions on poor households in Kenya (GoK, 2010). Additionally, Climate variability and extreme events predominantly associated with inter and intra-seasonal rainfall and temperature variability are significantly reducing productivity among farmers. Heavy dependence on rain-fed agriculture as the main source of livelihood refutes development by increasing poverty when climate extremes such as floods, droughts, diseases and pests strike.

Being a semi-arid region, Kitui County is among the most vulnerable regions in Kenya to climate variability and extremes. The manifestation of climate variability has resulted to reduced and unpredictable crop yields, crop failure and loss of livestock, leading to food shortages and over-reliance on emergency food-based interventions to meet local food deficit (GoK, 2005). There is evidently little understanding of the drivers and nature of climate related vulnerability by farmers in this area with regard to climate variability and extreme events. This study was therefore informed by the need to identify indicators and extent of vulnerability in order to inform farmers on the best interventions to enhance resilience, adaptive capacity and encourage adoption of adaptation strategies in line with SDG-13 on climate action.

1.3 Objectives of the study

The study was guided by the following objectives:

1.3. 1 Main objective

To assess farmers' vulnerability to climate variability and extreme events in arid, semi-arid, semi-humid and transitional from semi-humid to semi-arid agro-ecological zones of Kitui County.

1.3.2 Specific objectives

i. To determine the effects of climate variability and extreme events on farmers in the study areas.
ii. To determine the adaptive capacity of farmers to climate variability and extreme events in the study areas.
iii. To determine the adaptation strategies used by farmers in the study area to cope with climate variability and extreme events.

1.4 Research questions

The study sought to answer the following questions:

i. What are the effects of climate variability and extreme events on farmers in the study areas?
ii. What is the level of adaptive capacity of farmers to climate variability and extreme events in the study areas?
iii. What are the adaptation strategies used by farmers in the study areas to cope with climate variability and extreme events?

1.5 Significance of the study

The results of this study will provide authorities both at the County and national level with valuable inputs in formulating climate related policies and prioritizing adaptation strategies while targeting the most vulnerable agro-ecological zones to climate variability and extreme events. Results of the current study will also contribute towards Sustainable Development Goal 13 (SDG-13) particularly on the target of strengthening resilience and adaptive capacity of farmers to climate variability. Additionally, the research findings will avail evidence-based information on extent and state of exposure, sensitivity and adaptive capacity at agro-ecological level, thereby informing the County climate change pathway in the subsequent formulation of County Integrated Development Plans (CIDPs).

1.6 Justification of the study

Currently, there are only few studies in Kenya that have assessed farmers' vulnerability to climate variability and extreme events at household level. Most of the researches are macro in scope, focusing on ecosystems, Counties or regional levels. These studies fail to capture the farmer exclusive exposure, sensitivity, adaptive capacity and the best practices for households' adaptation to climate variability and extremes. This study was expected to narrow this gap by focusing on vulnerability at the farming households' level. Further, the current study provided insights into the components of vulnerability for households exposed to similar climate risks through analysis of how particular household characteristics relate to exposure, sensitivity and adaptive capacity. Kitui County was chosen because it has a wide range of agro-ecological zones (arid to sub-humid) with a big number of households heavily depending on climate sensitive livelihoods such as farming, livestock, bee keeping, fishing and natural resources.

1.7 Scope of the study

The study was conducted in four agro-ecological zones in Kitui County i.e. arid, semi-arid, semi-humid and transition from semi-arid to semi-humid zones. Four sub-locations-Yuku, Kasaini, Kaveta and Kauwi respectively, were purposively selected to represent the four agro-ecological zones. Vulnerability to climate variability and extreme events was taken as a function of exposure, sensitivity, and adaptive capacity. The number of occurrence(s) of extreme climatic related events such as droughts over a period of the past ten years were considered as the indicators of exposure. Conversely, human fatalities, livestock fatalities, share of natural and non-natural based income, water quantity and property damages as result of climate related disasters over a period of ten years were taken as the indicators of sensitivity for the purpose of this study. Indicators of adaptive capacity were the pointers of human, social, financial, physical and natural assets possessed by households. Explanatory variables including household head's age, gender, education level, farming experience, access to early weather information, access to credit facilities and agro-ecological zones were used to determine the probability of adoption or non-adoption of specific adaptation strategies by farmers.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Exposure to Climate Variability and Extremes

Khisa *et al. (*2014) conducted a study on the effects of climate change on small scale agricultural production and food security in Kitui District, Kenya utilizing data from 400 small scale farmers and meteorological data from nearby stations. The study reported significant rainfall variability over a period of thirty years and insignificant temperature variability in the region. An increase in the frequency of extreme weather events such as floods, dry spells, droughts and strong winds was noted. The results further suggested that despite temperature variations being small and insignificant, the effects such as prolonged droughts, death of livestock, crop failure and water shortage were severe and widely felt in the study area.

Oremo (2013) assessed small scale farmers' perceptions and adaptation measures to climate change in Kenya. The study reported large intra-and inter-annual rainfall variability with a significant negative trend in both the short and long rain seasons. Luni *et al*. (2012) probed rural households' vulnerability to climate change and extremes in Chepang mid-hills of Nepal and established that the higher rate historical changes in climatic variables and the frequency of climate related disasters, the higher the exposure of households therein to climate variability and extremes. In addition, minimum temperature and rainfall trends, and the number of climate related disasters contributed positively to the exposure index while maximum temperature contributed in the opposite direction. Absolute value of weights disclosed that maximum and minimum temperature and rainfall trends contributed more to the exposure index compared to the incidence of natural disasters. The study recommended that policy measures, development efforts and any other intervention towards improving adaptive capacity should primarily target the poorest rural households since they are more vulnerable to climate variability and related extreme events.

A study by Ndung'u *et al*. (2015) on vulnerability of rural communities to environmental changes revealed that mountain people of mid-hills of Himachal Pradesh in India faced social economic and biophysical vulnerabilities mediated by environmental change and amplified by the mountain specificities. The study further established a positive relationship between weights for drought, floods, landslides, hail events and the overall environmental hazard composite score and therefore a positive contribution to the exposure index. The study suggested that droughts, floods, landslides and hailing events had increased the exposure of mountain people in mid-hills of Himachal Pradesh in India. The researcher concluded that exposure of a locality to impacts of environmental change is the most important component determining the overall vulnerability of the people of mid-hills.

2.2 Sensitivity to Climate Variability and Extremes

Eboh (2009) examined the implications of climate variability on economic growth and sustainable development in Nigeria. The study suggested that the effects of climate variability and extremes on agriculture are projected to manifest through changes in land and water regimes, specifically changes in the frequency and intensity of drought, flooding, water quantity, worsening soil condition, desertification, diseases and pest outbreaks on crops and livestock.

Nancy *et al*. (2014) evaluated the impacts of climate variability on small scale farmers in North Kinangop, Kenya. The results indicated that small-scale farmers in North Kinangop were struggling with impacts of climate variability. According to the study, there was a strong association between perceived rainfall intensity variations and impacts on small-scale farmers in the area. A strong association was found between rainfall distribution, loss of crops, reduced quantity of fresh water, extreme climatic events occurrences and impacts on small-scale farmers. The study concluded that small-scale farmers have perceived climate variability to be impacting heavily on their agricultural activities as rainfall intensities, reliability and distribution continue to vary in time and space.

A study by Luni *et al*. (2012) on vulnerability of rural households to climate change and extremes in the Mid-Hills of Nepal established that deaths of family members, loss of properties (land, livestock, and crop) as a result of climate related disasters and income structure determined household's sensitivity to climate change and extreme events. The share of non-natural based income was found to decrease the overall household's sensitivity to climate change and extremes, while higher share of natural resource-based income increased the household's sensitivity to climate change and extremes. Further, the study found that livelihood impacts such as loss of livestock and crops to climate related disasters had more influence on the overall sensitivity index compared to the income structure.

Ndung'u *et al*. (2015) established that impacts of development projects and extreme events on land and water resources and household income structure were adequate in determining rural communities' sensitivity to environmental changes. The study showed a positive relationship between physical properties destroyed, livestock killed, land destroyed by extreme events, and high share of natural resource-based income with overall sensitivity index. Positive trend in availability of water resources and high share of non-natural resource-based income were found to have a negative relationship with sensitivity index. The absolute weight values indicated that share of natural resources-based income and share of non-natural resources-based income contributed more to the sensitivity index than the other indicators. Further, the results established that high share of non-natural resources-based income decreased the overall household sensitivity while higher share of natural resource-based income made the household more sensitive to environmental change.

2.3 Adaptive Capacity

A study by Eakin and Bojorquez-Tapia (2008) based on sustainable livelihood framework indicators pointed out that local capacity of adapting to climate perturbations and shocks is a function of indicators of access to different resources namely information, technology, wealth and finance, and institutional resources.

Andrew *et al. (*2016) explored the levels of adaptive capacity to climate variability among smallholder farmers in Manyoni District (an ASAL in Tanzania). The study revealed that 47.5% of the farmers interviewed belonged to low adaptive capacity category, while 40.8% belonged to moderate adaptive capacity category and only 11.7% of the respondents interviewed belonged to the high adaptive capacity level. This implies that majority of smallholder farmers in Manyoni District had a low resilience to the effects of climate variability and extremes given their low adaptive capacity.

A study by Recha *et al*. ((2017) to establish the state of adaptive capacity in semi-arid Tharaka sub-county in Kenya found out that diversity of livelihoods, two growing season and cultivation of drought tolerant crops (millet, green grams, sorghum and cowpeas) were indicators of adaptive capacity. The results indicated that adaptive capacity could be strengthened with efforts directed towards increased productivity and facilitating marketing of farm produce. Although households in Tharaka had more than one livelihood, their reliance on rainfall dependent livelihoods-livestock and crop produce, make them vulnerable to climate variability, especially drought. The researchers concluded that there is a need for diversification of livelihoods to reduce over-reliance on crops and livestock.

Research by Simotwo *et al*. (2018) in Trans-Mara East sub-county in Kenya to ascertain the validity of association between the smallholder's adaptive capacities and their socio-economic state of affairs revealed that education levels, income dependency ratio and farm sizes had positively significant association with their adaptive capacity. A positive, but significantly weak, association between individual's marital status and diversity of livelihood streams and their adaptive capacity was also reported. Education for instance, enhances skill acquisition among individuals, and in the process their possibility to occupy societal positions which can dispose them to a wide range of information, on adaptation, and more meaningful income streams. Larger farm sizes have been found to allow smallholders to allocate different portions of their land into various adaptable crop and livestock enterprises, thus raising their adaptive capacity (Fisher *et al*., 2015).

Agnes *et al*. (2017) studied the adaptive capacity of smallholder farmers to climate change. The study established that smallholder farmers in Busia County had low financial assets, moderate social and institutional assets and minimal technological assets. The low financial asset endowment was attributed to overreliance on climate sensitive rain-fed agriculture that is largely affected by erratic rainfall in Busia County. Therefore, the low financial and economic capacity among the smallholder farmers in Busia County reflects their limited ability to deal with and adapt to climate change effects. In turn, this affects smallholder farmers' ability to plan, prepare for, facilitate and implement adaptation measures. The researchers recommended that development activities and climate change efforts should focus on climate change awareness and diversification for both on-farm and off-farm livelihood activities.

2.4 Adaptations to climate variability and extremes

Fagariba *et al*. (2018) assessed climate change adaptation strategies and constraints in Northern Ghana. They found out that farmers in Sissala West District had adopted agro-forestry practice, drought-resistant crops, use of manure/mulching, planting season variation, different farming systems, irrigation method, use of inorganic fertilizer and use of virgin lands as the main adaptation strategies to climate variability and extremes. The study revealed that farmers perceived agro-forestry practices as the best adaptation method to improve microclimate, boost soil fertility, and reduce the high intensity of direct sunlight on the crops and soil nutrients. Results of the study showed that use of improved seed was ranked second in order of relevance to climate variability adaptations by the participants who suggested that improved crops could withstand drought, high temperature, and dry spell.

Further, farm manure/mulching, was seen as a good adaptation strategy to help boost soil fertility since most of the farmers had lots of livestock and crop residues and could hardly afford high prices of fertilizer. In addition, planting season variation was also seen as a good measure to tackle climate variability and extreme events. Key informant in this study were of the opinion that instead of planting at the regular farming season, farmers could prepare farmland and make all other necessary input ready so as to sow without delay as soon as the rain starts. This mitigation was suggested as a result of the irregular rainfall pattern in the study area. Crop rotation, mix cropping, land rotation, irrigation and use of in-organic fertilizer were also seen as good adaptation measures to climate variability and extremes. The researchers concluded that farmers' ability to adapt to climate change could be improved if the government intensified climate adaptation campaigns, increased access to weather information, and trained farmers on adaptable strategies including, but not limited to, alternative sources of livelihood.

Ogallo (2014) explored household vulnerability and adaptive capacity to impacts of climate change and variability in Soroti District, Eastern Uganda. The study results indicated that most households preferred multiple adaptation measures to deal with various climatic risks that included droughts, poor harvest, food shortage and floods. He found the main adaptation strategies to climate shocks in the study area to be crop diversification, shifting planting dates and diversifying from farming to non-farming activities. He also noted that a significantly smaller percentage of households practiced irrigation as an adaptation strategy. For the local people, crop diversification to an extent, guaranteed good harvests while cultivation of both short and long cycle crop varieties enabled the households to take advantage of the different maturing times of crops, to strengthen their resilience to impacts associated with climate variability. Crop diversification was identified as a potential farm-level adaptation to climatic variability in the District.

A study by Kasirye (2010) alluded that farmers in Uganda used mixed cropping and diversification of crops as a form of insurance against rainfall variability and pests' attack. The risk of complete harvest failure due to a climatic event such as drought, intense rainfall or high temperature spells, is reduced by having different crops in the same field or various plots with differing crops since not all crops and fields are affected the same way by such climate events. Although migration of family members was very rare in the study area, seasonal migration took place in search of employment to meet the household expenditure in times of food shortage. The study concluded that to improve resilience and enhance adaptation to climate change and variability, there was urgent need to alleviate poverty and unemployment within the district by enhancing the micro-financing efficiency and creating employment opportunities for the locals.

Mutunga *et al.* (2017) probed smallholder farmers' perceptions and adaptations to climate change and variability in Kitui County, Kenya. The study established that the main adaptation measures adopted by farmers in response to the decreasing precipitation included use of hybrid crop varieties, use of pesticides, use of animal manure, soil conservation, mixed crop, livestock farming and crop diversification. This is consistent with findings of a similar study by Oremo (2013) who identified soil conservation schemes, changing crop varieties, reducing the number of livestock, diversification of crop types and varieties, different planting dates, diversification to non-farming activity, water harvesting schemes and reducing the size of land under cultivation as the main adaptation measured adopted by smallholder farmers in the study area.

2.5 Factors influencing farmers' decisions to use adaptation strategies to climate variability and extremes

A study by Gbetibouo (2009) on understanding farmers' perceptions and adaptations to climate change and variability in Limpopo Basin, South Africa, identifies household characteristics, farm characteristics, institutional factors and local climatic and agro-ecological conditions as the key the determinants of the speed of farmers' adoption of adaptation strategies to climate change and variability. 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. Other factors include access to credit, extension services, membership to social and economic group and access to water (Gbetibouo, 2009).

Ndung'u and Bhardwaj (2015) assessed people's perceptions and adaptations to climate change and variability in Mid-Hills of Himachal Pradesh, India. The study identified education of the household head, farming experience, off farm income, access to credit and extension services as factors that significantly influenced adoption of adaptation strategies. However, household size, on farm income and gender of the household head were not significant in predicting adoption of adaptation strategies. It was concluded that factors such as education of the household head, farming experience, off farm income, access to credit and extension services influenced farmers' adaptive capacity and hence these need to be addressed in the study area.

Oremo (2013) examined small scale farmers' perceptions and adaptation measures to climate change in Kitui County, Kenya. The Heckman probit and multivariate biprobit models showed that extension service, educational attainment, membership to social and economic group, and access to water were the major factors influencing perception and adaptation uptake. 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 significantly determines whether or not they adapt to it. The researcher concluded that improving these factors would be important to enhance adaptive capacity at the household level. In this line the researcher recommended review farmer extension systems and design farm management adoption programs based on the socio-economic characteristics, such as years of schooling and membership to social groups of smallholder farmers in Mutomo, Ikutha and Lower Yatta.

A study by Mutunga *et al*. (2018) on factors influencing smallholder farmers' adaptation to climate variability in Kitui County showed that education level, farming experience, off- farm income, village of origin, access to credit facilities, access to climate information and weather forecasts significantly influenced farmers' adaptation to climate variability in Kaveta and Mikuyuni villages. Conversely, age and gender of the household head, household size, on-farm income, distance to the market and access to extension services were not significant in predicting the likelihood of adoption. The researcher recommended that County Government and the central government as well as non-governmental development partners should integrate the factors that significantly predict farmers' adaptation to climate variability into climate change policies, programs and projects.

2.6 Literature overview and Gaps

A considerable body of literature reviewed for this research addresses climate change vulnerability, climate variability and extremes, impacts on agricultural sector and possible adaptation strategies adopted by farmers. Generally, these studies suggested that farmers can overcome the adverse impact of climate change, climate variability and related extreme events by implementing adaptation measures (Oremo, 2013; Ogallo, 2014; Ndung'u and Bhardwaj, 2015; Mutunga *et al*., 2017 and Divine *et al*., 2018). Even when the reviewed studies emphasized adjustment of agricultural practices to climate variability and extremes in semi-arid environments, rarely did they identify vulnerability at agro-ecological zones level and hence household specific adaptation strategies to climate variability and extremes.

2.7 Conceptual Framework

Vulnerability to climate variability and extremes is a comprehensive multidimensional process affected by a large number of related indicators. It is a relationship between exposure to climate variations, sensitivity to the stressors and adaptive capacity of the households (Adger & Vincent, 2005, Luni *et al*., 2012). Exposure added to sensitivity will comprise the potential impact. Thus, vulnerability will be computed as potential impact minus adaptive capacity. The vulnerability assessment captured selected climatic and socio-economic characteristics of the farmers at household levels in Kitui that influenced exposure, sensitivity and adaptive capacity to climate variability and extreme events.

Exposure sought after specific extreme events including droughts, floods, livestock diseases, human-wildlife conflicts, community inter-border conflict and strong winds that have been experienced by the farmers. Sensitivity to climate extremes is as a result of exposure to climate variability and extremes and it captured fatalities, property damages and household's income structure. Adaptive capacity was captured as the livelihood assets and the various adaptation strategies that farmers had put in place.

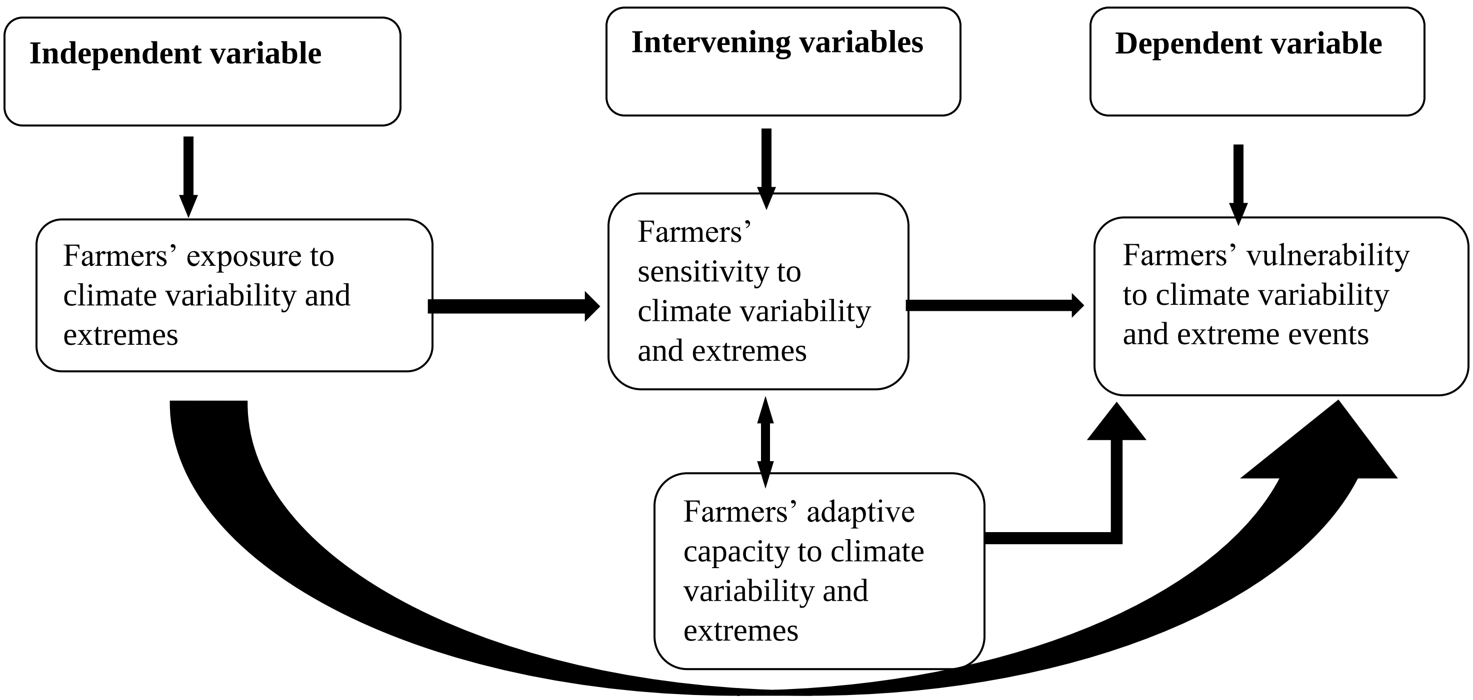

Figure 1.1: Conceptual Framework

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study area

The agro-ecological zones in Kitui County cut across the upper, lower and midland regions of the county ((Jaetzold *et al.,* 2006). In the upper region of Kitui County, two agro-ecological zones namely semi-arid and transition from semi-arid to semi-humid are dominant. The transitional zone covers Kauwi, Kithumula, Kabati, Kathivo and Kyambusya while the semi-arid covers Katheka area (Figure 3.1). The midland of Kitui County largely covers Kitui Central and its neighborhood. The key agro-ecological zones are semi-humid (Matinyani, Mutuni, Syongila, Kitui Township and makutano) and transition from semi-arid to semi-humid in Wililye. The lower region of Kitui County covers Kitui South and East. The region is characterized by arid, semi-arid and small portions of semi-humid and transitional agro-ecological zones. The semi-arid zone extends through Kabati, Kiongwe, Mulukya and Endau while the arid area covers Yuku. The small portions of semi-humid and transitional agro-ecological zones are in the far end Endau in Kitui East. The study was conducted in Yuku, Kaveta, Kauwi and Kasaini sub-locations which represented arid, semi-humid, transition from semi-arid to semi-humid and semi-arid agro-ecological zones respectively.

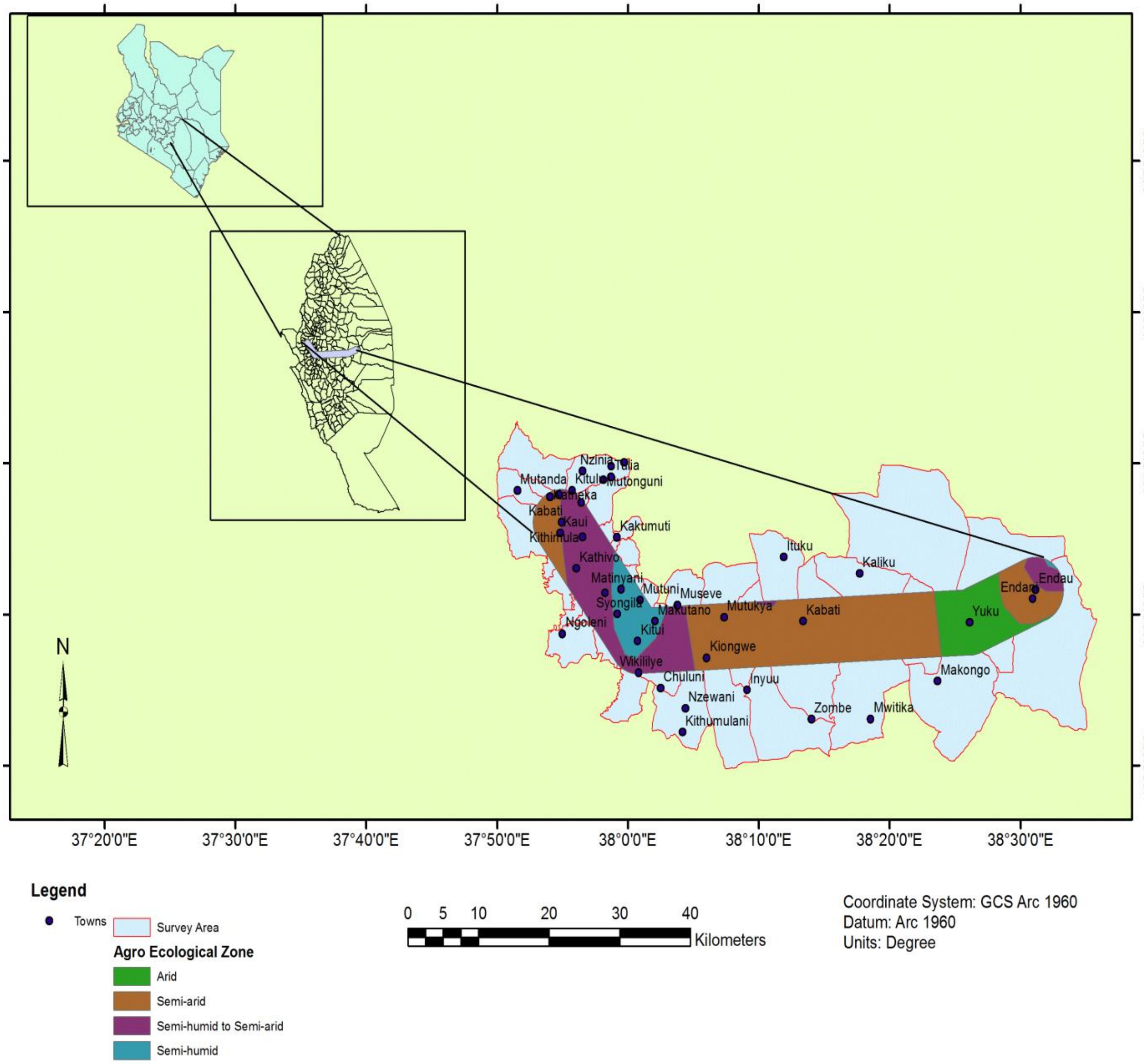

Figure 3.1: Map of the Study Area

(Source: ILRI GIS database)

3.1.1 Topography and climate

Generally, Kitui County is located in the southern part of Kenya. It borders Machakos and Makueni counties to the west, Tharaka Nithi and Meru counties to the north, Tana River to the east and TaitaTaveta to the south. Kitui County is located between longitudes 37º45´ and 39º0´ East and Latitudes 0º3.7´ and 3º0´ South (GoK, 2009). The county lies between 400m to 1,830m above sea level and generally slopes from west to east. The climate of the area is semi-arid with very erratic and unreliable rainfall. The temperatures range from an annual mean minimum of 14-22° centigrade to an annual maximum of 26-34° centigrade with the months of February and September being the hottest while July is the coldest month in the year. Rainfall is bimodal distributed within two seasons yearly and varies from 500-1050mm with about 40% reliability (GoK, 2009). The long rains are experienced between March and May and short rains between October and December. The short rains are considered more reliable than the long rains since it is during the short rains that farmers get their main food production opportunity. The soil types range from sedimentary rocks, red sandy soils, to clay black cotton soils which are generally low in fertility. The soils have a high tendency to cap under the raindrop impacts, thus vulnerable to soil erosion. These soils are relatively coarse, low in organic matter and generally shallow in depth.

3.1.2 Population and Economy

The household populations for the selected agro-ecological zones were 2082, 571, 2429 and 1911 for semi-arid, arid, semi-humid and transitional zone from semi-arid to semi-humid zones respectively (GoK, 2009). Mixed crop and livestock production are the mainstay of the County, with the balance between the two production systems being determined by the agro-ecological potential. Subsistence production is the main activity.

The semi-humid zone is suitable for sunflower, pigeon peas and maize (Zea mays) cultivation on the other hand, the transitional zone from semi-arid to semi-humid zone is a marginal cotton Zone. Food crops grown in the semi-humid zone include maize (Zea mays), sorghum (Sorghum spp.), finger millet (Eleusine coracana), common beans (Phaseolus vulgaris), cowpeas (Vigna unguiculate), green grams (Phaseolus aureus; normally grown for commercial purposes), and pigeon peas (Cajanus cajan). Cash crops include cotton (Gossypium hirsutum L.), sunflower (Helianthus annus) and some coffee (Coffea spp.; usually sold as mbuni).

Towards the arid zones, the climate is too dry for cotton. However, livestock, early maturing bulrush millet (Pennisetum typhoideum), finger millet (Eleusine coracana) and foxtail millet (Setaria italica) are widely planted in the zone. Very early maturing sorghum is also possible there. At present, maize is still widely planted, with subsequent crop failures and the risk of famine especially during dry years in which the rains are insufficient even for sorghum and millet (Recha *et al*., 2017).

3.2 Data collection

3.2.1 Primary data

Primary data was collected principally by means of household survey interview schedules and direct personal observation.

3.2.2 Household survey interview schedules

Semi structured coded interview schedules were used targeting household respondents for quantitative and qualitative data. The interview schedules had measures such as Likert scales to capture attitude and level of agreement to statement scales (Monette *et al*., 2013). Likert scales provided ordinal data that was valuable during analysis than nominal data could have been. Data collected using the interview schedules included proxy indicators of households' adaptive capacity, exposure and sensitivity such as data on the five household assets, number of climate related disasters experienced over a period of ten years, property damaged by climate related disasters, trend of water quality over the past ten years, share of natural and non-natural resource-based income, adaptation strategies used by farmers to cope with climate variability and extreme events and factors that determined adoption of the adaptation strategies.

3.2.3 Direct personal observation

Direct field observations and photography was applied to identify critical aspects of climate variability and extreme events, their impacts and household situations that the respondents did not reveal in the interview schedules. Data collected by this means included household assets ownership and property damages as a result of climate related disasters.

3.2.4 Secondary data

Secondary data was obtained from an array of sources including Kenya Bureau of Statistics, Kitui Meteorological Department and County ministry of Agriculture. Data on total population and number of households in Yuku, Kaveta, Kauwi and Kasaini sub-locations was obtained from Kenya Bureau of Statistics. Annual mean minimum and maximum temperature and total annual average rainfall from 1998 to 2018 were obtained from Kitui Meteorological Department. County ministry of Agriculture provided data on number of farming households as well as the frequency of extension services offered in the study areas.

3.3 Research design

Descriptive survey design was adopted since the study was a description of variables as they existed on the ground devoid of manipulation. The target population and unit of study were households in different agro ecological zones. The design of different ecological zones was adopted with the aspiration to understand the differences in farmers' vulnerability (exposure, sensitivity and adaptive capacity) to climate variability and extremes among households in different agro-ecological zones (arid, semi-arid, semi-humid and transition from semi-arid to semi-humid).

3.4 Sampling Procedure

Purposive sampling was used to select sub-locations representative of agro-ecological zones. From a total of 3410 households from the four sub-locations representing four agro-ecological zones (Yuku 390 households representing arid zone, Kaveta 1040 households representing semi-humid zone, Kasaini 380 households representing semi-arid zone and 1600 households in Kauwi representing transition zone from semi-humid to semi-arid), a representative sample of households was calculated to fit the most productive criterion that was relevant to research objectives.

According to Mugenda and Mugenda (2003), 10% of the total population is an ample representative of the population thus adequate for analysis and generalization. Therefore, 10% of the total household population in each sub-location was calculated and applied as the sample size for this study.

Hence, the sample size for the study was 341 households (39, 104, 38 and 160 for Yuku, Kaveta, Kasaini and Kauwi sub-locations respectively). Proportionate sampling was used compute the number of households to interview per village depending with the population of households in each village. A starting point was selected conveniently from the nearest shopping centre and then systematic sampling applied in selecting the households that formed the study sample where every 10^{th} household was interviewed.

Table 3.1: Operationalization of variables

Variables	Criteria	Instrument	Analysis
Farmers' exposure to climate variability and extremes	Frequency of climate related natural disasters	Household survey interview schedule	One way ANOVA
The sensitivity of farmers to climate variability and extremes	Human and livestock fatalities Damages on properties Income structure, water quantity	Household survey interview schedule Personal Observation	One way ANOVA
Farmers' adaptive capacity to climate variability and extremes	Human assets, Natural assets, Physical assets, Social assets and Financial assets	Household survey interview schedule	One way ANOVA
Farmers' adaptation strategies to climate variability and extremes	Adaptation strategies adopted by farmers in response to climate variability and extremes Factors influencing adoption of adaptation strategies by farmers	Household survey interview schedule Personal Observation	Cross tabulations and Chi-square test for independence Binary logistic regression

3.5 Data analysis

Quantitative data was coded and entered into the computer for analysis. Ms Excel and Statistical Package for Social Sciences (SPSS version 20) packages were used to run both descriptive and inferential statistics as shown in Table 3.1. One-way ANOVA was performed to compare means for indicators of exposure, sensitivity and adaptive capacity. Chi square test for independence and crosstabs were used to analyze adaptation strategies adopted by farmers in different agro-ecological zones. Logistic regression was performed to assess the influence of socio-economic factors on farmer's ability to adapt to climate variability and extremes (Table 3.1).

3.6 Selection of Vulnerability Indicators

Developing an index to measure vulnerability was helpful in comparing different agro-ecological zones and provide insights into the fundamental determiners of vulnerability. Following the definition of vulnerability by IPCC (2001), vulnerability in this study was taken to be a function of exposure, sensitivity, and adaptive capacity. Indicators of these components were identified based on theories that provide insight into the nature and causes of vulnerability and their functional relationship with vulnerability established for the purpose of vulnerability index construction.

Frequencies of occurrence of extreme climatic related events were taken as indicators of exposure (Table 3.2). It was hypothesized that the higher the frequency of climate related disaster the higher the exposure of the agro-ecological zone to climate variability and extremes thus an increasing functional relationship (↑).

Table 3.2: Indicators of Exposure

Indicators	Unit	Hypothesized relationship	Functional relationship with vulnerability
Number of floods over a period of ten 10 years	Number	+	↑
Number of droughts over a period of ten 10 years	Number	+	↑
Number of storms/strong wind over a period of ten 10 years	Number	+	↑
Number of livestock diseases over a period of ten 10 years	Number	+	↑
Number of wild/forest fires over a period of ten 10 years	Number	+	↑
Number of community inter-border conflicts over a period of ten 10 years	Number	+	↑
Number of human- wildlife conflicts over a period of ten 10 years	Number	+	↑

Following Marshall *et al*. (2009), livelihood impacts of climate related disasters, nature of income and water availability were taken as the sensitivity indicators. Human fatalities, livestock fatalities, share of natural and non-natural based income, water quantity and property damages (land, houses, roads, trees and crop) due to climate related disasters over a period of ten years represented sensitivity for the purpose of this study. It was hypothesized that higher livelihood impacts of climate related disasters, higher share of natural resource-based income, and increased frequency of water sources drying up increase sensitivity thus an increasing functional relationship with vulnerability (↑; Table 3.3). On the converse, higher share of non-natural resource based remunerative income sources will reduce the sensitivity thus a decreasing functional relationship with vulnerability (↓).

Table 3.3: Indicators for sensitivity

Component Indicators	Description of Indicators	Unit	Hypothesized relationship	Functional relationship with vulnerability
Fatalities	Human fatalities (dead and injured family members) due to climate related disasters over a period of 10 years	Number	+	↑
	Livestock fatalities (dead and injured cows, goats, sheep) due to climate related disasters over a period of 10 years	Number	+	↑
Damages to property	Total land damaged by all the climate related disasters over a period of 10 years	Area in Acres	+	↑
	Total crop and trees damage due to all the climate related disasters over a period of 10 years	Number	+	↑
	Houses damaged due to all the climate related disasters over a period of 10	Number	+	↑
Income structure	Share of natural resource-based income (farm wages, livestock production, forest products, honey sales, handicraft, sand harvesting, fish farming) to total income	Ksh	+	↑
	Share of non-natural resource-based income (salaried job, remittance, skilled non-farm job, small business returns) to total income	Ksh	–	↓
Trends of water quantity	Number of times the rivers, boreholes, shallow wells, springs, earth dams, water pans and sand dams have dried up over a period of 10 years	Number	+	↑

For this study, indicators for adaptive capacity were based on the DFID sustainable livelihoods framework, where adaptive capacity is taken to be an emergent property of human, social, natural, physical and financial assets possessed by the households (DFID, 1999; Ellis, 2000). Any indicator with a positive relationship with adaptive capacity results to a decreasing functional relationship (↓) with vulnerability while indicators that reduce adaptive capacity ultimately increase vulnerability (↑; Table 3.4). Human asset is represented by highest level of education in the family which translate to schooling years, trainings or vocational courses attended by family members, years involved in farming and persons in the household with salaried employment. These indicators are hypothesized to have a positive relationship with adaptive capacity while they have a decreasing functional relationship with vulnerability.

Size of productive and unproductive land and ownership of small and large livestock were taken as indicators for natural asset. Higher share of productive land and higher number of bullocks translate to higher food self-sufficiency, thus higher adaptive capacity whereas higher share of unproductive land has an opposite effect (Table 3.4).

Social assets were represented by memberships to formal community-based organizations (CBOs), cooperative societies, access to credit facilities and access to extension services. It was hypothesized that the higher the memberships and the better the access to credit and extension services, the higher will be the adaptive capacity of the households.

Gross household annual income, total annual household savings and total annual earnings from livelihood strategies represented financial asset in this study. Better performance of these indicators is hypothesized to enhance adaptive capacity as it means greater availability of resources at disposal to maximize positive livelihood outcomes.

Physical asset is represented by gadgets owned and used to access information, sources of timely early warning weather information and distances to nearest motorable road, market, water source and health facility. Ownership of gadgets, access to extension services and high number of sources of timely early warning weather information will increase adaptive capacity while distances to nearest motorable road, market, water source and health facility are hypothesized to be inversely related to adaptive capacity.

Table 3.4: Indicators for Adaptive Capacity

Component Indicators	Description of Indicators	Unit	Hypothesized relationship	Functional relationship with vulnerability
Human Asset	Highest level of education in the family	Number	+	↓
	Number of schooling years	Number	+	↓
	Trainings or vocational courses attended by family	Number	+	↓
	Number of years involved in farming	Number	+	↓
	Persons in the household with salaried employment	Number	+	↓
Natural Asset	Size of productive land	Acres	+	↓
	Size of unproductive land	Acres	_	↑
	Small livestock (goats and sheep)	Number	+	↓
	Large livestock (bullock, cows, oxen)	Number	+	↓
Physical Asset	Gadgets owned and used to access information	Number	+	↓
	Sources of timely early warning weather information	Number	+	↓
	Distance to nearest motorable road	Kilometres	_	↑
	Distance to the nearest market	Kilometres	_	↑
	Distance to nearest water source	Kilometres	_	↑
	Distance to nearest health facility	Kilometres	_	↑
Social Asset	Number of CBO membership	Number	+	↓
	Number of cooperative societies	Number	+	↓
	Number of credit facilities accessed in the last 5 years	Number	+	↓
	Access to extension service in last 1 year	Number	+	↓
Financial Assets	Gross household annual income	Ksh	+	↓
	Total household savings	Ksh	+	↓
	Total annual earnings from livelihood strategies	Ksh	+	↓

3.7 Construction of Vulnerability Index

Having selected the indicators of different components of vulnerability and their functional relationship with vulnerability identified, the UNDP's Human Development Index (HDI) (UNDP, 2006) was followed to normalize them. This is done in order to standardize values and also to obtain figures which are free from the units and scales of the indicators such that the normalized values all lie between 0 and 1.

Variables with a ↑ functional relationship with vulnerability were normalized using the formula:

$$X_{ij}=\frac{X_{ij}-Min_{i(X_{ij})}}{Max_{i(X_{ij})}-Min_{i(X_{ij})}}$$

Where; *Xij* is the value of the indicator *j* corresponding to region *i*

$Min_{i(X_{ij})}$ is the smallest value of the indicator in all the study areas and $Max_{i(X_{ij})}$ is the largest value of the same indicator.

On the other hand, normalized score for variables with a ↓ functional relationship with vulnerability were computed using the formula:

$$Y_{ij}=\frac{Max_{i(X_{ij})}-X_{ij}}{Max_{i(X_{ij})}-Min_{i(X_{ij})}}$$

Equal weights were given to all variables and simple average of all the normalized scores used to construct the vulnerability index by using the formula:

$VI=\frac{\sum_j X_{ij}+\sum_j Y_{ij}}{K}$ Where K is the number of indicators.

As applied by Ndung'u and Bhardwaj (2015), vulnerability index of each agro-ecological zone was calculated as:

V = E + S –AC

Where, V is the vulnerability index, E is exposure index, S is sensitivity index and AC is adaptive capacity index.

This can also be expressed as:

V = PI-AC

Where, PI is potential impact index=E+S and AC is adaptive capacity index.

Since equal weights were assigned to all indicators, component indices were arrived at by obtaining the means of normalized values for all indicators.

Vulnerability indices were then used to rank the different agro-ecological zones in terms of vulnerability. A zone with highest index was said to be most vulnerable and was assigned the rank 1, the zone with next highest index was given rank 2 and so on.

3.8 Factors influencing adoption of adaptation strategies in the study areas

The logistic regression model as outlined by Gujarati (2004) and applied by Mutunga *et al*. (2018) was used as presented below, albeit in reduced form

$Y_i = \alpha + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + \beta_{10}X_{10}$……………………… (equation 1)

Where; Y_i is a dichotomous dependent variable (adoption or non-adoption of specific adaptation strategies). α is the Y- intercept; β_1- β_{10} is a set of coefficients to be estimated; X_1-X_{10} are explanatory variables hypothesized by theory and empirical work to influence farmers' adaptation to climate variability and extremes. (Table 3.5)

Equation (1) can be expressed as;

$\text{Logit}(p) = \log(p / 1- p) = \alpha + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + \beta_{10}X_{10}$………. (Equation 2)

Where p is probability that Y= 1 i.e. p =probability (Y= 1).

In term of probability the equation 2 can be expressed as:

$$P = \frac{\exp(\alpha + \beta1X1 + \ldots \ldots \ldots \ldots \ldots \ldots \beta10X10)}{1 + \exp \alpha + \beta1X1 \ldots \ldots \ldots \ldots \ldots \beta10X10} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (Equation\ 3)$$

Table 3.5: Description of explanatory variables that predict probability of farmers' adapting to climate variability and extremes in the study areas

Variables	Description of variables	Hypothesized influence on adaptation
X_1	Age of the household head	+/-
X_2	Gender of household head	+/-
X_3	Education level of the household head	+
X_4	Farming experience	+
X_5	On-farm income (annual income from farming activities)	+
X_6	Off-farm income (annual income from none farm activities)	+
X_7	Access to credit	+
X_8	Access to extension services	+
X_9	Access to climate information and weather forecast	+/-
X_{10}	Agro-ecological zones	+/-

CHAPTER FOUR

4.0 RESULTS

Information on demographic and social economic characteristics of household heads, indicators of exposure, sensitivity and adaptive capacity and adaptation strategies was collected, analyzed and study results presented in graphs, and tables of percentages, frequencies and means.

4.1 Socio-economic characteristics of households in Yuku, Kaveta, Kauwi and Kasaini sub-locations

This section sought after social- economic characteristics of the household head such as gender, age, education level, marital status and income distribution.

4.1.1. Gender of the household heads

In the current study, a total of 341 respondents from Yuku, Kaveta, Kauwi and Kasaini sub-locations from Kitui County were interviewed with 39 from Yuku, 104 Kaveta, 160 Kauwi and 38 Kasini. It was clear that majority of the household heads in the study areas were males. The results indicated that 74.4, 64.4, 71.9 and 78.9% households in Yuku, Kaveta, Kauwi and Kasaini sub-locations, respectively were male headed while 25.6, 35.6, 28.1 and 21.1% households in Yuku, Kaveta, Kauwi and Kasaini, respectively were female headed (Figure 4.1).

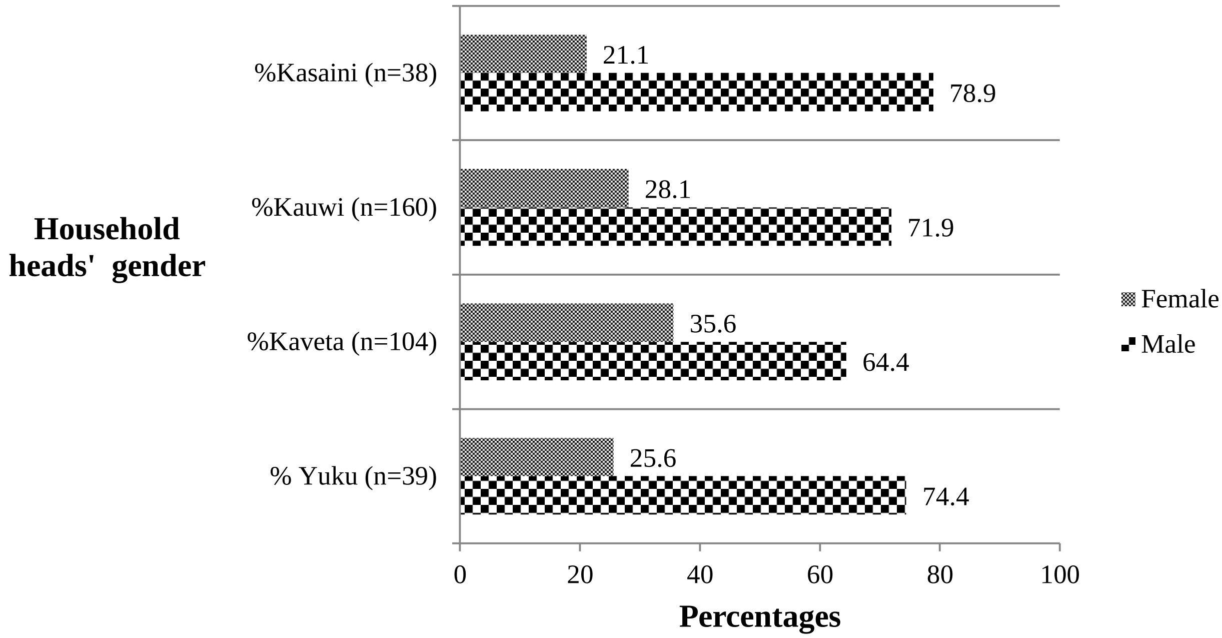

Figure 4.1: Distribution of households' heads by gender in the study area

4.1.2 Age of household heads in Yuku, Kaveta, Kauwi and Kasaini sub-locations

Information on age of household heads in the four sub-locations was collected, analyzed and results presented in Table 4.1. Analysis of results indicated that the minimum age of household heads was 26 years in Yuku and Kaveta, 22 years in Kauwi and 30 years in Kasaini. Maximum age of household heads was 85 years, 89 years, 100 years and 95 years for Yuku, Kaveta, Kauwi and Kasaini sub-locations respectively. It is evident that the mean average ages for the four sub-locations are between 55-58 years and the standard deviation 14.90, 14, 53, 15.54 and 15.52 for Yuku, Kaveta, Kauwi and Kasaini sub-locations respectively. This demonstrates that the age of household heads was centrally distributed.

Table 4.1: Age distribution of household heads in the study area

Sub- locations	Mean	Std. Deviation	Minimum	Maximum
Yuku	57.64	14.895	26	85
Kaveta	55.86	14.526	26	89
Kauwi	55.58	15.541	22	100
Kasaini	55.24	15.515	30	95

4.1.3 Education level of household heads

Close scrutiny of the data presented in Table 4.2 revealed that Kaveta sub-location had the highest educational qualifications among household heads with only 4.8% not having formal education, 47.1% having achieved primary education, 32.7% secondary education, 13.5% college, 1% graduate level and another 1% post graduate level of education. Kasaini sub-location followed with 13.2% of household heads having no formal education, 44.7% (primary education), 28.9% (secondary education), 10.5% (college) and 2.6% (post-graduate).It was evident that Yuku sub-location had the least educational qualifications among household heads where 30.8% of the household heads had no formal education, 43.6% had primary education, 25.6% secondary education and none of the household heads had acquired post-secondary education. Kauwi sub-location had the second least educational qualification where 12.5% of household heads had no formal education, 51.3% acquired primary education, 26.9% secondary education, 8.8% college and 0.6% had acquired post-graduate studies.

Table 4.2: Percentage (%) distribution of household heads' education levels in the study area

Education level of household heads	**Yuku (n=39)**	**Kaveta (n=104)**	**Kauwi (n=160)**	**Kasaini (n=38)**
None	30.8%	4.8%	12.5%	13.2%
Primary	43.6%	47.1%	51.3%	44.7%
Secondary	25.6%	32.7%	26.9%	28.9%
College	0.0%	13.5%	8.8%	10.5%
Graduate	0.0%	1.0%	0.0%	0.0%
Post-graduate	0.0%	1.0%	0.6%	2.6%
Totals	100.0%	100.0%	100.0%	100.0%

4.1.4 Marital status of household heads

It was apparent from Table 4.3 that majority of household heads in the study areas were monogamously married with 76.9 in Yuku, 67.3 kaveta, 61.3 Kauwi and 73.75% Kasaini. Further, analysis of results indicated that none of household heads in Yuku was divorced/ separated (0.0%) while1, 1.3, and 2.6% in Kaveta, Kauwi and Kasaini, respectively had divorced or separated. On the other hand, Kauwi was found to have the highest percentage of single household heads at 20.6% followed by Kasaini, Kaveta and Yuku with 10.5, 8.7 and 5.1%, respectively. Polygamously married household heads were more in Kauwi (5.6), followed by Kasaini (5.3), Kaveta (4.8) and Yuku (2.6%).

Table 4.2: Distribution (%) of household heads by marital status in the study area

		Yuku (n=39)	**Kaveta (n=104)**	**Kauwi (n=160)**	**Kasaini (n=38)**
Marital status of household head	Single	5.1%	8.7%	20.6%	10.5%
	Monogamously Married	76.9%	67.3%	61.3%	73.7%
	Polygamously married	2.6%	4.8%	5.6%	5.3%
	Divorced/ separated	0%	1%	1.3%	2.6%
	Widowed	15.4%	18.3%	11.3%	7.9%

4.1.5 Distribution of household's income

Analysis of results (Table 4.4) indicated that the mean average household annual income from farm produce was highest in Yuku sub-location (Kshs. 34,534.62), followed by Kauwi (Kshs. 29,486.90), Kasaini (Kshs. 25,536.84) while Kaveta sub-location had the least (Kshs. 21,999.04). Further, the results revealed that Kaveta sub-location had the highest amount of mean off-farm annual income (Kshs. 110,663.50) whereas Yuku had the least at Ksh 23,164.10 (Table 4.3).

Kauwi sub-location had a comparatively higher mean average for both annual income from farm produce and off farm annual income (Kshs. 29,486.90 and 71,483.10 respectively) than Kasaini sub-location which had the second least mean average for both annual income from farm produce and the off farm annual income (Kshs. 25,536.84 and 54636.84 respectively). The average means values for both annual income from farm produce and off farm annual income did not show a statistically significant difference across the sub-locations (p>0.05).

Table 4.4: Mean income distribution among households in the study areas (Kshs)

Indicators	**Aggregate (n= 341)**	**Yuku (n=39)**	**Kaveta (n=104)**	**Kauwi (n=160)**	**Kasaini (n=38)**	**P-Value**
Annual income from farm produce	27340.30 (78782.91)	34534.62 (56551.37)	21999.04 (29630.82)	29486.87 (105415.95)	25536.84 (58262.74)	0.82
Annual off farm income	76029.03 (227897.81)	23164.10 (56326.56)	110663.46 (315400.23)	71483.13 (205725.13)	54636.84 (91270.93)	0.18

Note: Figures in parenthesis indicate standard deviation

4.2 Effects of climate variability and extreme events on farmers in the study areas

4.2.1 Indicators of exposure in the study area

Close analysis of the results indicated that, number of floods, droughts and livestock diseases over a period of ten years was highest in Yuku (at 1.03, 7.56 and 4.92 respectively) followed by Kauwi (0.72, 6.69 and 3.41), Kasaini (0.37, 4.79 and 2.45) and Kaveta at 0.08, 4.46 and 1.84. There was a statistically significant difference in the mean values for the number of floods, wild/ forest fires, community inter-border conflicts and incidences of human-wildlife conflict across the four sub-locations (p<0.05; Table 4.5). Further results indicated that wild/ forest fires and community inter-border conflict incidences were highest in Yuku (0.92 and2.90) followed by Kaveta (0.11 and 0.66), Kauwi (0.03 and0.16) and Kasaini (0.00 and 0.13). From the results, it is clear that the number of climate related natural disasters over a period of ten years were highest in Yuku at 39.00 followed by Kauwi (14.53), Kaveta (10.68) and Kasaini (10.50). The mean values for total climate related natural disasters showed a statistically significant difference across the four sub-locations.

Table 4.5: Mean values for Indicators of Exposure in the study area

Indicators	Aggregate (n= 341)	Yuku (n=39)	Kaveta (n=104)	Kauwi (n=160)	Kasaini (n=38)	P-Value
Floods	0.41 (1.16)	1.03 (2.07)	0.08 (0.34)	0.71 (1.16)	0.37 (1.65)	0.00**
Droughts	5.90 (9.80)	7.56 (5.39)	4.46 (4.70)	6.69 (13.32)	4.79 (3.97)	0.18
Storms/strong winds	3.82 (8.07)	6.49 (6.76)	2.87 (5.18)	4.11 (10.21)	2.50 (4.10)	0.02**
Wild/forest fires	0.15 (1.40)	0.92 (3.72)	0.11 (0.99)	0.03 (0.25)	0.00 (0.00)	0.00**
Livestock diseases	3.00 (7.74)	4.92 (5.82)	1.84 (3.42)	3.41 (10.35)	2.45 (3.78)	0.14
Community inter-border conflicts	0.62 (2.22)	2.90 (4.72)	0.66 (2.00)	0.16 (0.99)	0.13 (0.81)	0.00**
Human-wildlife conflicts	0.42 (2.04)	3.08 (5.10)	0.04 (0.24)	0.05 (0.22)	0.26 (1.62)	0.00**
Total disasters	14.32 (32.41)	26.90 (71.90)	10.06 (10.24)	14.89 (27.59)	10.50 (10.10)	0.00**

Note: Figures in parenthesis indicate standard deviation

****** indicate significant at 5% level of significance

4.2.2 Indicators of Sensitivity in the study area

Scrutiny of the results indicated that mean values for human fatality due to the entire climate related natural disasters over a period of ten years were statistically significant ($p<0.05$) across the sub-locations with highest incidences in Yuku (45.18) followed by Kaveta (0.19), Kauwi (0.09) and Kasaini (0.05) sub-locations (Table 4.6). Livestock fatality mean values were also statistically significant across the sub-locations where Yuku had the highest incidences of livestock deaths due to climate related natural disasters at 204.44, followed by Kauwi (5.56), Kasaini (4.39) and Kaveta sub-location (2.24). Additionally, the mean values for the number of houses, road distance and productive land damaged by the disasters revealed a statistically significant difference across the sub-locations ($p<0.05$). Generally, total livelihood damage caused by all the climate related natural disasters was highest in Yuku (256.37) and lowest in Kaveta (2.96). Conversely, the mean values for share of natural resource-based income and non-natural resource-based income did not show a statistically significant difference across the sub-locations ($p>0.05$). Kaveta had the highest share of non-natural resource-based income (Kshs. 164,466.30), followed by Kauwi (Kshs. 138,441.30), Kasaini (Kshs. 62,418.40), and Yuku (Kshs. 33,423.10). In contrast, Yuku had the highest share of natural resource-based income at Kshs. 60,909.00 followed by Kasaini (Kshs 54,471.10), Kauwi (Kshs. 46,828.20) and Kaveta at Kshs 40,054.90.

Table 4.6: Mean values for fatalities, damages and income indicators of sensitivity in the study area

Indicators	Aggregate (n= 341)	Yuku (n=39)	Kaveta (n=104)	Kauwi (n=160)	Kasaini (n=38)	P-Value
Human fatalities	5.28(71.64)	45.18(209.94)	0.19(0.78)	0.09(0.45)	0.05(0.32)	0.00**
Livestock fatalities	27.16 (208.42)	204.44 (593.00)	2.24 (4.76)	5.56 (10.23)	4.39 (8.08)	0.00**
Number of houses damaged	0.36 (1.39)	1.87 (3.50)	0.14 (0.53)	0.21 (0.59)	0.03 (0.16)	0.00**
Roads damaged	0.12 (1.10)	0.85 (3.17)	0.03 (0.22)	0.00 (0.00)	0.00 (0.00)	0.00**
Productive land damaged	0.98 (3.71)	4.03 (9.82)	0.28 (0.76)	0.81 (1.71)	0.36 (1.07)	0.00**
Share of total natural resource-based income	47325.20 (98017.40)	60909.00(52706.00)	40054.90 (54726.30)	46828.20 (125985.50)	54471.10(92137.90)	0.68
Share of total non-natural resource-based income	130169.80 (475022.90)	33423.10(58392.80)	164466.30 (633050.40)	138441.30 (337962.20)	62418.40(100181.70)	0.36

Note: Figures in parenthesis indicate standard deviation

****** indicate significant at 5% level of significance

Vulnerability of water resources to climate variability was indicated the number of times the water sources had dried up over a period of ten years as indicated in Table 4.7. The mean sums for the number of time rivers, boreholes, shallow wells, springs, earth/sand dams and water pans had dried up over a period of ten years was highest in Yuku (26.37) followed by Kauwi (18.64), Kasaini (16.46) and Kaveta (13.46) and the mean values were statistically significant across the sub-locations ($p<0.05$).

Table 4.7: Mean values for indicators of water quantity in water sources in the study areas

Indicators	Aggregate (n= 341)	Yuku (n=39)	Kaveta (n=104)	Kauwi (n=160)	Kasaini (n=38)	P-Value
Number of times the nearest river had dried up (over a period of 10 years)	5.23 (4.59)	5.44 (4.79)	4.31 (4.48)	5.76 (4.53)	5.32 (4.68)	0.04**
Number of times the nearest borehole had dried up (over a period of 10 years)	1.41 (3.37)	2.85 (4.72)	1.53 (3.25)	1.08 (3.04)	1.05 (3.11)	0.03**
Number of times nearest shallow well dried up (over a period of 10 years)	3.45 (4.40)	4.72 (4.85)	2.47 (3.96)	3.69 (4.46)	3.82 (4.49)	0.03**
Number of times nearest spring dried up (over a period of 10 years)	1.95 (3.98	3.87 (5.38)	1.43 (3.45)	1.91 (3.86)	1.58 (3.70)	0.01**
Number of times nearest earth/sand dams dried up (over a period of 10 years)	3.03 (4.35)	4.82 (4.50)	1.73 (3.41)	3.55 (4.65)	2.53 (4.28)	0.00**
Number of times water pans dried up (over a period of10 years)	2.62 (4.90)	4.67 (8.79)	1.99 (3.94)	2.65 (4.23)	2.16 (395)	0.03**
Number of times other sources dried up (over a period of 10 years)	1.21 (3.40)	4.00 (6.10)	1.02 (2.86)	0.87 (2.76)	0.26 (1.62)	0.00**

Note: Figures in parenthesis indicate standard deviation

** indicate significant at 5% level of significance

4.2.3: Exposure and sensitivity indices in the study area

All the indicators of exposure contributed to exposure index positively as hypothesized. In general, examination of indicator variables for exposure presented in Table 4.8 indicated that climate related disasters were highest in Yuku (7.00) followed by Kauwi (2.34), Kasaini (0.67) and Kaveta (0.39).

In addition, Yuku sub-location had the highest indices values for sensitivity indicators (normalized value =1) except for frequency of nearest river drying up over a period of ten years (normalized value =0.78) and share of non-natural resource-based income (normalized value =0.00). Kaveta sub-location on the contrary, had the least indices values for sensitivity indicators except for share of non-natural resource-based income where the value was highest (normalized value =1).

Table 4.8: Exposure and sensitivity indices in the study area

		Sub-locations			
	Indicators	**Yuku**	**Kaveta**	**Kauwi**	**Kasaini**
Indicator variables for exposure	Floods	1.000	0.000	0.660	0.310
	Droughts	1.000	0.000	0.720	0.110
	Strong winds	1.000	0.090	0.400	0.000
	Wild/forest fires	1.000	0.120	0.030	0.000
	Livestock diseases	1.000	0.000	0.510	0.200
	Community inter-border conflicts	1.000	0.190	0.010	0.000
	Human-wildlife conflict	1.000	0.000	0.010	0.050
	Sub-total scores	**7.00**	**0.40**	**2.34**	**0.67**
Indicator variables for sensitivity	Human fatalities	1.000	0.003	0.001	0.000
	Livestock fatalities	1.000	0.000	0.016	0.010
	Houses damaged	1.000	0.060	0.098	0.000
	Roads damaged	1.000	0.035	0.000	0.000
	Productive land damaged	1.000	0.021	0.141	0.000
	Natural resource income	1.000	0.000	0.324	0.691
	Non-natural resource income	0.000	1.00	0.199	0.779
	Rivers dried up	0.779	0.000	1.000	0.697
	Boreholes dried up	1.000	0.267	0.017	0.000
	Shallow wells dried up	1.000	0.000	0.542	0.600
	Springs dried up	1.000	0.000	0.197	0.061
	Earth/sand dams dried up	1.000	0.000	0.589	0.259
	Subtotal scores	**10.779**	**1.386**	**2.88**	**3.15**

4.2.4: Potential impact indices in the study area

The results presented in Table 4.9 revealed that exposure to climate variability and extremes was highest in Yuku (exposure index=1.000), followed by Kauwi (0.334), Kasaini (0.096) and Kaveta sub-location (0.057). Additionally, the results indicated that Yuku sub-location had the highest sensitivity index (0.853) followed by Kasaini (0.315), Kauwi (0.240) and Kaveta sub-locations (0.106). Generally, potential index was highest in Yuku (1.85), followed by Kauwi (0.58), Kasaini (0.41) and Kaveta sub-location at 0.16. Despite Kauwi performing better in sensitivity index than Kasaini, its exposure index was comparatively high resulting to higher potential impact index in the sub-location compared to Kasaini.

Table 4.9: Potential impact indices in the study area

Sub-locations	Exposure index	Sensitivity index	Potential impact index	Rank
Yuku	1.000	0.853	1.853	1
Kaveta	0.057	0.106	0.163	4
Kauwi	0.334	0.240	0.574	2
Kasaini	0.096	0.315	0.411	3

4.3 Adaptive capacity indicators in the study area

4.3.1 Indicators of physical and natural assets in the study area

Analysis of results presented in Table 4.10 on adaptive capacity showed that mean values for physical assets had a statistically significant difference across the study areas ($p<0.05$) except for distances to the nearest motorable road. The mean average values for the indicators of physical assets revealed that Kaveta had relatively higher possession of these assets with mean values of 1.47 for the number of sources of timely weather information followed by Kasaini 1.24, Yuku 1.18 and Kauwi sub-location 1.09 (Table 4.10). Further, the results showed that distances to the nearest motorable roads, markets, water sources and health facilities were longest in Yuku (2.53, 4.83, 4.23 and 8.31 respectively) followed by Kaveta (2.28, 2.35, 1.21 and 2.62), Kasini (0.62, 3.00, 1.04 and 3.50) and Kauwi at (0.98, 2.53, 1.10 and 2.92 respectively).

The results also showed that Yuku sub-location was highly endowed with natural assets with mean values for size of productive land (8.72), small livestock (8.56) and large lovestock at 6.15 followed by Kauwi at (4.72, 7.13 and 2.32) respectively, Kasaini (3.80,5.84 and 2.13) and Kaveta sub-location at 2.34, 2.50 and 1.26. The mean values for the natural assets were statistically significant across the four sub-locations ($p<0.05$).

Table 4.10: Mean values for indicators of physical and natural assets in the study area

Assets and their indicators	Aggregate (n= 341)	Yuku (n=39)	Kaveta (n=104)	Kauwi (n=160)	Kasaini (n=38)	P-Value
Natural asset						
Size of productive land (acres)	4.35 (5.71)	8.72 (10.83)	2.34 (2.77)	4.72 (5.09)	3.80 (3.67)	0.00**
Size of unproductive land (acres)	1.20(4.30)	6.00 (10.70)	0.62 (1.78)	0.56 (1.82)	0.57(1.21)	0.00**
Small livestock	5.74(8.81)	8.56 (11.17)	2.50 (3.12)	7.13(10.40)	5.84(6.75)	0.00**
Large livestock	2.42(3.50)	6.15 (6.85)	1.26 (1.74)	2.32 (2.74)	2.13(2.22)	0.00**
Physical assets						
Number-sources of weather information	1.23 (1.00)	1.18 (0.89)	1.47 (1.23)	1.09 (0 85)	1.24 (1.03)	0.03**
Distance to nearest motorable road (KM)	1.51(6.27)	2.53(3. 32)	2.28(10.90)	0.98(1.90)	0.62(0.88)	0.22
Distance in Km to the nearest market	2.79 (3.24)	4.83 (7.36)	2.35 (1.58)	2.53 (2.32)	3.00 (2.37)	0.00**
Distance to nearest Water source (KM)	1.49 (2.41)	4.23 (5.53)	1.21 (1.20)	1.10 (1.30)	1.04 (1.22)	0.00**
Distance to nearest health facility (KM)	3.51(3.75)	8.31 (7.44)	2.62 (2.01)	2.92 (2.59)	3.50(2.08)	0.00**

Note: Figures in parenthesis indicate standard deviation

** indicate significant at 5% level of significance

4.3.2 Indicators of human, financial and social assets in the study area

The current results showed a statistically significance difference in the mean values for human assets across the study areas ($p<0.05$). Results in Table 4.11 revealed that Kaveta had the highest values for number of formal schooling years (13.07), family members with salaried jobs (0.91), trainings and vocational courses in the family (0.82) followed by Kasaini (12.42, 0.66 and 0.50 respectively), Kauwi (at 12.40, 0.50 and 0.45) and Yuku sub-location at (10.85, 0.44 and 0.44).

Further, the results indicated that Kaveta had the highest financial assets in terms of gross monthly income and monthly savings (Kshs 26,453.40 and 2,933.00 respectively) followed by Kauwi (Kshs 19,583.50 and 2,121.40), Kasaini (Kshs 15,944.70 and 1,592.10) and yuku sub-location (Kshs. 13, 095.50 and 843.80). Analysis of results revealed that total earning from livelihoods were highest in Kasaini (Kshs. 208,534.40) followed by Kaveta (Kshs. 189,789.10), Kauwi (Kshs.149, 416.10) and Yuku (Kshs. 127,039.30). Mean values for the financial assets did not show a statistically significant difference across the study areas ($p>0.05$).

Analysis of results on social assets indicated that memberships to CBOs and cooperative societies were highest in Kaveta with mean values of (17.65 and 4.16 respectively) followed by Kasaini (3.82 and 3.71), Kauwi (2.79 and 1.70) and Yuku sub-location (2.57 and 1.00). In addition, the results indicated that the amount of credit accessed by farmers was highest in Kaveta (Kshs. 1,951.90), followed by Kauwi (Kshs. 1,896.60), Kasaini (Kshs. 1,789.80), and Yuku (1,282.30). The mean values for the social assets did not show a statistically significant difference across the four sub-locations ($p>0.05$) except for the number of extension services accessed last 1 year. The results showed that Kaveta had relatively better access to extension services over a period of one year with mean value of 0.95 followed by Yuku 0.59, Kauwi 0.33 and Kasaini sub-location at 0.18.

Table 4.11: Mean values for Indicators of human, financial and social assets in the study area

Indicators	Aggregate (n= 341)	Yuku (n=39)	Kaveta (n=104)	Kauwi (n=160)	Kasaini (n=38)	P-Value
Human asset						
Highest number of formal schooling years	12.43 (4.42)	10.85 (3.98)	13.07 (4.74)	12.40 (4.18)	12.42 (4.68)	0.02**
Number of persons in the family with salaried jobs	0.64 (1.07)	0.44 (0.85)	0.91 (1.31)	0.50 (0.85)	0.66 (1.26)	0.01**
Trainings/vocational courses in the family	0.57 (0.97)	0.44 (0.85)	0.83 (1.19)	0.45 (0.85)	0.50 (0.76)	0.01**
Farming experience by household head	25.63 (16.55)	19.28 (12.20)	26.59 (15.35)	26.42 (17.64)	26.16 (17.99)	0.04**
Financial asset						
Gross household income /month	20513.80 (53271.60)	13095.50(19727.90)	26453.40 (68048.00)	19583.50(52978.30)	15944.70(24359.50)	0.51
Household savings /month	2161.60 (7275.60)	843.80 (2516.00)	2933.00 (9593.90)	2121.40 (6440.50)	1592.10 (6532.50)	0.45
Total annual earnings from livelihood strategies	165687.30(415236.40)	127039.30 (115022.80)	189789.10(477960.40)	149416.10(344170.20)	208534.40(648955.60)	0.72
Social asset						
CBO memberships (number)	8.06 (38.62)	2.57 (4.00)	17.67 (64.50)	2.79 (4.41)	3.82 (6.89)	0.21
Number of extension services accessed last 1 year	0.53 (1.48)	0.59 (1.09)	0.95 (2.35)	0.33 (0.81)	0.18 (0.46)	0.00***
Cooperative society memberships (number)	7.82 (3819.31)	1.00 (0.00)	4.16 (14.15)	1.70 (5240.59)	3.71 (364.80)	0.69
Credit facilities accessed /last 5 years	1414.86 (9482.25)	1282.26(6561.2)	1951.94 (8895.1)	1896.63(11175.1)	1789.84 (4866.5)	0.84

Note: Figures in parenthesis indicate standard deviation

****** indicate significant at 5% level of significance

4.3.3 Adaptive capacity indices in the study area

Examination of the results established that Kaveta had the highest adaptive capacity index (0.693) followed by Yuku sub-location (0.366). Kauwi and Kasaini sub-locations were third and fourth (0.360 and 0.326 respectively) as indicated in Tables 4.12. Despite Kaveta sub-location having highest indices for physical assets, human assets and majority of financial and social assets, the sub-location had lowest values for natural assets. Yuku sub-location ranked second as regards adaptive capacity index owing to the high values for natural assets such as size of land, size of productive land and number of small and large bullocks owned. However, Yuku was lowly endowed with human, physical, financial and social assets.

Table 4.12: Adaptive capacity indices in the study area

Indicator variables for adaptive capacity	Sub-locations	Yuku	Kaveta	Kauwi	Kasaini
Physical assets	Gadgets owned	0.026	1.000	0.322	0.000
	Reliable weather information sources	0.237	1.000	0.000	0.395
	Nearest market	1.000	0.000	0.073	0.262
Human assets	Schooling years	0.000	1.000	0.698	0.707
	Family salaried jobs	0.000	1.000	0.128	0.468
	Trainings/vocational in family	0.000	1.000	0.026	0.154
	Farming experience	0.000	1.000	0.977	0.941
Natural assets					
	Productive land	1.000	0.000	0.373	0.229
	Unproductive land	1.000	0.011	0.000	0.002
	Small livestock	1.000	0.000	0.764	0.551
	Large livestock	1.000	0.000	0.217	0.178
Financial assets	Gross income	0.000	1.000	0.486	0.213
	Household savings	0.000	1.000	0.612	0.358
	Earnings from livelihood strategies	0.000	0.770	0.275	1.000
Social assets	Access to extension services	0.532	1.000	0.195	0.000
	CBO memberships	0.000	1.000	0.015	0.088
	Access to credit facilities	0.424	1.000	0.9552	0.000
Sum of scores		6.219	11.781	6.112	5.546
Adaptive capacity index		0.366	0.693	0.360	0.326
Rank		2	1	3	4

4.3.4 Overall vulnerability indices in the study area

Scrutiny of the results presented in Table 4.13 revealed that among the selected study sites, Yuku sub-location was the most vulnerable to climate variability and extremes (1.487) owing to very high potential impact index (1.853) and a low adaptive capacity index (0.366) relative to Kaveta. Further, the results indicated that Kaveta sub-location was the least vulnerable to climate variability and extremes explained by lowest potential impact index (0.163) coupled with highest adaptive capacity index (0.693). Despite Kauwi sub-location having a higher adaptive capacity index (0.360) than Kasaini sub-location (0.326), it has the second highest vulnerability index (0.214) owing to its higher potential impact index (0.574).

Table 4.13: Vulnerability Indices in the study area

Sub-locations	Exposure index	Sensitivity index	Potential impact index	Adaptive capacity index	Vulnerability index	Rank
Yuku	1.00	0.853	1.853	0.366	1.487	1
Kaveta	0.057	0.106	0.163	0.693	-0.530	4
Kauwi	0.334	0.240	0.574	0.360	0.214	2
Kasaini	0.096	0.315	0.411	0.326	0.085	3

4.4 Adaptation strategies used by farmers in response to climate variability and extremes in the study areas

Results from the study showed that a greater percentage of the households had adopted multiple adaptation strategies to climate variability and extremes. As indicated in Table 4.14, the most practiced adaptation strategies within the study areas was use of organic manure at 80.6% (48.75% in Yuku, 79.8% Kaveta, 88.8%, Kauwi and 81.6% Kasaini). Change of planting time was practiced by73.6% of the households (82.1% in Yuku, 73.1% Kaveta, 72.5% Kauwi and 71.1% Kasaini) while mixed crop and livestock system had been adopted by 73.3% of households (87.2% in Yuku, 61.5% Kaveta, 78.1% Kauwi and 71.1% Kasaini). Implementation of soil conservation techniques was also a common adaptation strategy adopted by 72.4% of households (69.2% in Yuku, 78.8% Kaveta, 67.5% Kauwi and 78.9% Kasaini) whereas use of pesticides was used by 71.6% (59.0% in Yuku, 75.0% Kaveta, 69.4% Kauwi and 84.2% Kasaini). Other common adaptation stragegies used by farmers in the study areas included crop diversification 69.8% (with71.8% in Yuku, 60.6% Kaveta, 66.2% Kauwi and 68.4% Kasaini), planting drought resistant crops 66.0% (76.9% in Yuku, 60.6% Kaveta, 66.2% Kauwi and 68.4% Kasaini), putting trees for shading 61.3% (with 25.6% in Yuku, 75% Kaveta, 58.1% Kauwi and 73.7% Kasaini) and use of improved crop variety 59.5% (30.8% in Yuku, 65.4% Kaveta, 63.8% Kauwi and 55.3% Kasaini). In contrast, only a few of the respondents had adopted aquaculture (0.9% in Kaveta and Kasaini sub-locations only), migration to urban areas (3.5%), irrigation (9.1%), purchase of insurance (7.3%), shifting from livestock to crop farming (11.7%), use of animal feed supplements (14.4%), increasing livestock diversity and moving heard from one place to another both at 6.5%. Other adaptation strategies such as water harvesting schemes (36.7%), water re-using (42.2%), reducing number of livestock (38.7%), finding off-farm jobs (41.3%), use of chemical fertilizers (27.0%), minimum tillage (39.3%), agro-forestry (47.2%), seeking veterinary services (40.2%) and use of Integrated Pest Management (IPM; 45.2%) were averagely used within the four sub-locations.

Scrutiny of the results presented in Table 4.14 indicated that there was a statistically significant relationship between agro-ecological zones and adoption of mixed crop livestock system (X^2=13.2, $p<0.05$),building water-harvesting schemes(X^2=8.6, $p<0.05$), planting trees for shade (X^2=32.27, $p<0.05$), irrigation (X^2=17.01, $p<0.05$), use of chemical fertilizer (X^2=-2.77, $p<0.05$), use of organic manure (X^2=32.27, $p<0.05$), improved crop variety (X^2=16.34, $p<0.05$), agro-forestry (X^2=54.36, $p<0.05$), integrated pest management(X^2=9.88, $p<0.05$), moving herd from one place to another (X^2=12.34, $p=0.05$), migration to urban areas (X^2=6.95, $p<0.05$), leasing land (X^2=6.34, p<0..05)and use of pesticides (X^2=7.00, $p<0.05$). Additionally, the results indicated that adoption of crop diversification, planting drought resilient crops, water re-using, changing planting time, shifting from livestock keeping to crops farming, implementing soil conservation techniques, buying insurance, reducing number of livestock, increasing livestock diversity, use of animal feed supplements, finding off-farm jobs, land leasing, minimum tillage, seeking veterinary officers' support and aquaculture practices were not significantly associated with the agro-ecological zones ($p>0.05$).

Table 4.14: Adaptation strategies (%) used by farmers in response to climate variability and extremes

Adaptations	Yuku (n=39) %	Kaveta (n=104) %	Kauwi (n=160) %	Kasaini (n=38) %	Total (n=341) %	X^2 Value	P-Value
Shift from livestock keeping to crops farming	10.3	17.3	8.8	10.5	11.7	4.63	0.20
Mixed crop livestock system	87.2	61.5	78.1	71.1	73.3	13.2	0.00**
Crop diversification	71.8	69.2	70	68.4	69.8	0.13	0.99
Plant drought resilient crops	76.9	60.6	66.2	68.4	66.0	3.54	0.32
Build a water-harvesting scheme	30.8	47.1	34.4	23.7	36.7	8.6	0.04**
Practice reuse of water	28.2	49	41.9	39.5	42.2	5.25	0.16
Changing planting time	82.1	73.1	72.5	71.1	73.6	1.68	0.64
Soil conservation techniques	69.2	78.8	67.5	78.9	72.4	5.1	0.17
Buy insurance	7.7	9.6	4.4	13.2	7.3	4.76	0.19
Put trees for shading	25.6	75	58.1	73.7	61.3	32.27	0.00**
Irrigation	2.6	18.3	4.4	10.5	9.1	17.01	0.00**
Reduce the number of livestock	53.8	39.4	35.6	34.2	38.7	4.75	0.19
Increase livestock diversity	5.1	3.8	7.5	10.5	6.5	2.62	0.45
Use animal feeds supplements	7.7	17.3	15	10.5	14.4	2.65	0.45
Migrate to urban area	10.3	2.9	1.9	5.3	3.5	6.95	0.04**
Find off-farm job	51.3	40.4	41.9	31.6	41.3	3.14	0.37
Lease your land	2.6	6.7	1.9	0	3.2	6.34	0.02**
Use of chemical fertilizer	2.6	55.8	8.8	50	27.0	92.77	0.00**
Use of organic fertilizer (manure)	48.7	79.8	88.8	81.6	80.6	32.27	0.00**
Use minimum tillage	41	48.1	35.6	28.9	39.3	6.02	0.11
Use improved crop varieties	30.8	65.4	63.8	55.3	59.5	16.34	0.00**
Use of pesticides	59	75	69.4	84.2	71.6	7.00	0.01**
Agro-forestry	17.9	75	35.6	50	47.2	54.36	0.00**
Integrated pest management	28.2	55.8	43.8	39.5	45.2	9.88	0.02**
Seeking support from veterinary officers	53.8	43.3	34.4	42.1	40.2	5.75	0.13
Move herd from one place to another	17.9	2.9	5	10.5	6.5	12.34	0.01**
Aquaculture	0	1.4	1.2	0	0.9	0.94	0.82

Note ** indicate significant at 5% level of significance

4.5 Factors influencing farmers' adaptation to climate variability and extremes in Yuku, Kaveta, Kauwi and Kasaini sub-locations

A logistic regression was performed to ascertain the effects of household heads' age, gender, education level, farming experience, agro-ecological zone, on-farm income, off-farm income, access to credit facilities, access to extension services and access to climate information and weather forecasts on the likelihood that farmers adequately adapted to climate variability and extremes. Results of the logistic regression analysis showed that gender, education level, farming experience and age significantly ($p<0.5$; Table 4.15) influenced farmers' adaptation to climate variability and extremes in the study areas. However, on-farm income, off-farm income, access to extension services, access to credit facilities and access to climate information and weather forecasts were not significant in the study area ($p>0.5$). The results indicated that 12% of variation in adoption of adaptation strategies was explained by explanatory variables in the equation (Nagelkerke'sR^2= 0.120) and 65.3% of the cases were correctly classified cases.

Table 4.15: Results of logistic regression on factors influencing farmers' adoption of adaptation strategies to climate variability and extreme in the study area

Factors	Coefficient	Wald statistic	P-value	Odds ratio
Agro-ecological zone	.060	.046	0.77	1.06
Gender	.656	5.965	0.04**	1.93
Access to credit facilities	.398	2.495	0.158	1.49
Education level	.351	.763	0.00**	1.42
Access to extension services	-.038	.230	0.63	0.96
Access to early warning weather information	.005	.002	0.68	1.01
Farming experience	.015	2.259	0.01**	1.02
On- farm income	.000	.985	0.44	1.00
Off-farm income	.000	1.522	0.77	1.00
Age	.016	2.483	0.00**	1.02
Constant	-1.357	6.094	0.01**	0.26

Note**:** ** indicate significant at 5% levels of significance

Further, examination of the results presented in Table 4.15 showed that education level of the household head (coefficient=0.35, p= 0.00; odds ratio=1.24), gender of the household head (coefficient=0.66; p=0.04; odds ratio=1.93), farming experience (coefficient=0.01; p=0.01; odds ratio=1.02) and age (coefficient=1.02; p=0.00; odds ratio=1.02) positively influenced farmers' adaptation to climate variability in Yuku, Kaveta, Kauwi and Kasaini sub-locations. Conversely, the results indicated that number of times of access to extension negatively influenced adaptation of farmers to climate variability and extremes in the study areas services (coefficient=-0.038; p= 0.631; odds ratio=0.96).

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effects of climate variability and extremes on farmers in Yuku, Kaveta, Kauwi and Kasaini sub-locations, Kitui County

5.1.1 Exposure of farmers to climate variability and extremes in the study area

The current study established that, the number of climate related natural disasters over a period of ten years were highest in Yuku (39.00) followed by Kauwi (14.53), Kaveta (10.68) and Kasaini (10.50). There was a statistically significant difference in the means for total climate related natural disasters across the four agro-ecological zones (Table 4.5). It was evident that farmers in Yuku (arid) and Kauwi (transitional from semi-arid to semi-humid) experienced higher number of climate related natural disasters compared to those in semi-arid and semi-humid zones.

The high number of disasters highlighted the zones' exposure to climate variability and extremes due to property and infrastructural damages. This could be attributed high number of floods, droughts, strong winds, wild/ forest fires, community inter-border conflicts, incidences human-wildlife conflict and livestock diseases. The situation was exacerbated by the observation that the arid and transitional zones practiced poor agricultural systems such as mono-cropping with very little cover crops and agro-forestry practices. Therefore, the shallow soils were often left bear, thus prone to disasters such as floods and droughts.

Conversely, those in Kaveta (semi-humid) and Kasaini (semi-arid) experienced comparatively lower incidences of the disasters thus reducing their exposure to extreme events. The farmers in these zones practiced intense agriculture characterized by planned agro-forestry practices, mixed cropping and growing of cover crops such as sweet potatoes. The practices reduced the susceptibility of the zones to climate related disasters such as floods, droughts and crop pests and diseases. Moreover, farmers in Kaveta and Kasaini had better access to extension services and weather information thus better adapted against the disasters.

Similar findings by Ndung'u *et al*. (2015) while working in Mid-hills of Himachal Pradesh in India indicated that increase in natural disasters such as droughts, floods among others lead to property destruction and subsequent exposure of farmers to hazards. In addition, findings by

Luni *et al*. (2012) imply that number of natural disasters experienced in a locality is a salient component to determine the overall exposure of the locality.

5.1.2 Sensitivity of farmers in the study area to climate variability and extremes

Results in Table 4.6 revealed that total asset and livelihood damage caused by the climate related natural disasters was highest in Yuku and lowest in Kaveta sub-location. For example, the number of human fatalities, livestock fatalities, house damages, and productive land damaged by all the climate related disasters were highest in Yuku and lowest in Kaveta. This could be explained by the high intensity of the climate related natural disasters experienced in Yuku causing severe effects like human and livestock deaths and injuries.

In addition, the proximity of Yuku sub-location to Tsavo national park and Kitui South national reserve increased human-wildlife conflicts as farmers reported cases where hyenas invaded their livestock resulting to deaths and injuries. Moreover, neighboring pastoral communities often experience severe droughts leading to invasion into the area in search for pasture and water. This eventually raises tension between the communities thus increasing the incidences of community inter-border conflicts. Further, higher sensitivity of farmers to climate variability and extremes in Yuku can be explained by high incidences of drought and short but very intensive and destructive rainfall over the last two decades, thereby causing more damages in the arid zone.

The share of natural resource-based income was highest in Yuku followed by Kasaini, Kauwi and lowest in Kaveta sub-location. On the contrary, share of non-natural resource-based income was highest in Kaveta sub-location and lowest in Yuku sub-county. Higher share of natural resource-based income compared to non-natural resource-based income in Yuku and Kasaini could be attributed to the nature of livelihoods in the two zones which were predominantly based on natural-resource based activities notably agriculture, livestock, sand harvesting, handicraft and forestry. The education levels in the two areas were lower compared to Kaveta and Kauwi, making it difficult for people from these areas to secure professional jobs out of the usual natural based activities. Moreover, Yuku and Kasaini are quite far from the county headquarters where most non-natural income generating opportunities are found.

Conversely, the higher ratio of non-natural resource-based income to natural resource-based income in Kaveta and Kauwi sub-locations could be explained by the nature of livelihoods in the areas. Income generating activities in these areas are primarily based on non-natural resources such as formal employment, remittances, non-skilled off farm employment and other trainings. Kaveta and Kauwi are near the headquarters where formal and non-formal off farm opportunities were available. In addition, education levels in Kaveta and Kauwi were relatively high making it easier for residents to acquire skilled jobs in the headquarters or even outside the County. Increase in share of non-natural resource-based income had a negative functional relationship with sensitivity while increase in share of natural resource-based income increased farmers' sensitivity as such resources are highly dependent on climate.

The results in Table 4.7 showed that the number of times the nearest water sources had dried up over a period of ten years were significant across the agro-ecological zones with the highest numbers in Yuku and lowest in Kaveta sub-location. This can be attributed to the extreme water scarcity in Yuku where farmers visited the water sources frequently in search for household and livestock's water. This was unlike Kaveta, where there were minimal visits to water sources as the people had alternative sources of water like tapped water and rain harvested water storages.

The current study is in agreement with a study by Luni *et al.* (2012) who while working on vulnerability of rural households to climate change and extremes in the Mid-Hills of Nepal also used deaths of family members, loss of properties (land, livestock, and crop) due to climate related disasters and income structure as determinants of household sensitivity. The researcher concluded that income structure and livelihood impact due to climate related disasters influenced the overall sensitivity index. The study also revealed that high share of non-natural based income assists to decrease the overall household sensitivity, while higher share of natural resource-based income makes the household more sensitive to climate change and extremes.

The current study is also in line with the findings of Ndung'u *et al.* (2015) who established a positive relationship between physical properties destroyed by extreme events, livestock killed by extreme events, land destroyed and share of natural resource-based income with sensitivity index.

5.1.3 Potential impact index

Potential index was calculated as the sum of exposure index and sensitivity index. The results indicated that exposure to climate variability and extreme was highest in Yuku (exposure index=1.000) and least in Kaveta (exposure index=0.057) sub-location. Kauwi and Kasaini sub-locations were second and third (exposure indices, 0.334 and 0.096 respectively) in terms of exposure (Table 4.9). The high exposure index in Yuku sub-location could be attributed to high incidences of climate related natural disasters such as floods, droughts, strong winds, forest fires and community inter-border conflicts. On the contrary, low exposure index in Kaveta could be explained by minimal occurrences of the climate related disasters over a period of ten years. The mean value for total disasters was higher in Kauwi compared to Kasaini sub-location as indicated in Table 4.5 resulting to higher exposure in Kauwi sub-location.

On the other hand, the current study found that Yuku sub-location had the highest sensitivity index (0.853) followed by Kasaini (0.315), Kauwi (0.240) and Kaveta sub-locations at 0.106 (Tables 4.9). High sensitivity in Yuku sub-location could be explained by high mean values for sensitivity indicators particularly human and livestock fatalities as well as houses, productive land and roads damaged by extreme climatic events. The mean value for non-natural resource-based income was lowest in Yuku significantly contributing to the high sensitivity index. Conversely, Low sensitivity in Kaveta sub-location could be attributed to lesser incidences of the sensitivity indicators coupled with highest mean values for non-natural resource-based income which as hypothesized reduced sensitivity of the area to climate variability and extremes. Despite ranking lower in terms of sensitivity index than Kasaini, Kauwi ranked much higher in terms of exposure index making the potential impacts in Kauwi second after Yuku, followed by Kasaini and least in Kaveta sub-location (Table 4.9).

5.2 Adaptive capacity of farmers to climate variability and extremes in the study area

Close scrutiny of the mean values of the assets revealed that Kaveta had comparatively higher asset possession while Kasaini had the least asset possession among the study sub-locations. Based on results presented in Table 4.11, Kaveta ranks best in three of the asset categories (human, financial and social assets) and second-best in physical assets, thereby scoring the highest in overall adaptive capacity. The total scores for individual indicators in Tables 4.12 shows that Kaveta scores the highest in terms of possession of human assets (highest formal schooling years in the family, trainings and vocation courses attended by family members, farming experience and number of family members with salaried jobs), has comparatively higher number of sources of timely weather information, highest number of extension services accessed in the last one year, highest monthly income, highest monthly saving, and best access to credit.

Yuku stood the last in terms of human, financial, social assets and natural assets and fares relatively high in physical assets. Overall, it ranked second in terms of adaptive capacity. Kauwi ranked the third and Kasaini fourth in terms of adaptive capacity index (Table 4.12).

Based on results, the primary policy focus in the arid zones particularly Yuku, should be to increase their access to financial assets and improve human assets which could go a long way in improving other assets categories including social asset, physical asset and natural asset. Financial assets enable households to make investment in education and the savings can be used as capital for investments like buying good quality land or buying necessary inputs for cash crop cultivation such as cotton and the emerging "Ndengu (green gram) revolution". However, financial asset in Yuku was found to be very limited contrary to Kaveta due to the remoteness of the area, long distances to the market and fewer opportunities that generate cash income. Development of infrastructure that creates employment opportunities for cash income generation in the area is thus recommendable. In addition, educational qualification among interviewed household heads was very low in the arid- Yuku sub-location thus having several negative consequences in their livelihoods. Low educational qualification could have hindered them from attaining the skills required to make more productive use of the available natural and physical resources. Policies should be geared towards improving the literacy rate of the community, and also towards providing trainings and vocational education for capacity building and skills development, so that they can diversify their livelihoods to more remunerative sources.

The current trend of results is in line with findings of Agnes *et al*. (2017) who established that smallholder farmers in Busia County had low financial/economic adaptive capacity, moderate social, institutional, knowledge and minimal informed farming decision making resources. The low financial and economic resource was explained by overreliance on climate sensitive rain- fed agriculture largely affected by erratic rainfall in Busia County. Therefore, the low financial and economic capacity among the smallholder farmers in Busia County reflected their limited ability to deal with and adapt to climate change effects. This affected smallholder farmers' ability to plan, prepare for, facilitate and implement adaptation measures. This finding is in agreement with Simotwo *et al*. (2018) whose study revealed that education levels, dependency ratio and farm sizes had positively significant association with farmers' adaptive capacity in Trans-Mara East. A positive, but significantly weak, association between individual's marital status and diversity of livelihood streams and their adaptive capacity was also reported. Education for instance, enhanced skill acquisition among individuals, and in the process increasing their possibility to occupy societal positions which could dispose them to a wide range of information, on adaptation, and more meaningful income streams.

5.2.1 Overall vulnerability index

The results in Table 4.13 indicated that among the selected study sites, Yuku sub-location ranked the most vulnerable to climate variability and extremes (1.487) while Kaveta sub-location was the least vulnerable (_0.530). Kauwi and Kasaini sub-locations were second (0.214) and third (0.085) respectively with regard to vulnerability index. Yuku had the highest exposure and sensitivity indices (1.00 and 0.853 respectively) coupled with a lower adaptive capacity index (0.366) relative to Kaveta. Consequently, it was the most vulnerable sub-location. Despite Kauwi having relatively higher adaptive capacity and lower sensitivity index compared to Kasaini, it still ranks the second most vulnerable sub-location owing to its high exposure index. In spite of having lower adaptive capacity than Kauwi sus-location, Kasaini sub-location ranked better in overall vulnerability as it faced less exposure. The two least vulnerable sub-locations have the least exposure to climate variability and extremes. However, higher sensitivity coupled with low adaptive capacity results to higher vulnerability in Kasaini compared to Kaveta. Yuku and Kauwi had the highest potential impact indices attributable to high incidences of extreme climate related disasters as demonstrated in Table 4.5. This translates to intensive implications on livelihoods thus high sensitivity indices in the two sub-locations.

The results are in consonance with findings of Luni *et al*. (2012) who established that the most vulnerable households are always the ones with the lowest adaptive capacity, highest exposure and sensitivity indices irrespective of the locality. Thus, improving the adaptive capacity of these vulnerable households will also invariably reduce their sensitivity and finally decreases their overall vulnerability. Agro-ecological zones' comparison of vulnerability showed that despite having higher adaptive capacity, such capacity may not be fully realized in the face of higher exposure and sensitivity (Ndung'u *et al.,* 2015).

5.3 Adaptation strategies used by farmers in response to climate variability and extremes in the study area

Results in Table 4.14 indicated that there was a statistically significant relationship between agro-ecological zones and adoption of building water-harvesting schemes, planting trees for shade, irrigation, use of chemical fertilizer, use of organic manure, improved crop variety, agro-forestry, integrated pest management, moving herd from one place to another, migration to urban areas and use of pesticides ($p<0.05$). Adoption of most of these adaptation strategies such irrigation, aquaculture and integrated pest management as was highest in Kaveta and lowest in Yuku. This could be attributed to the intense resource investment needed for installation and maintenance of the strategies. Kaveta was better endowed with financial, human and technological resources compared to the Kauwi, Kasaini Yuku and thus better placed to take up the adaptation strategies that required high resource investment. Moreover, unlike Yuku sub-location, Kaveta sub-location was characterized by intense agriculture which features smart agriculture practices including agro-forestry, integrated pest management, use of chemical fertilizers and use of improved crop varieties. More often, these agricultural practices are also autonomous adaptation strategies to cope with climate variability and extreme events. The results are in agreement with the findings of Mutunga *et al.* (2017) who established a significant difference in the adaptation measures used by farmers in Mikuyuni and Kaveta sub-locations in Kitui County.

The study revealed that very few respondents had adopted irrigation, aquaculture and buying of insurance. However, adoption of irrigation and aquaculture was highest in Kaveta sub-location and lowest in Yuku sub-county. This could be attributed to scarcity of water to support irrigation and aquaculture, inadequate financial and technological capacity among the farmers in Yuku sub-location. The high levels of adoption of these strategies in Kaveta sub-location could be explained by the fact that farmers in the area had adequate water to support irrigation and aqua-culture. Moreover, Kaveta sub-location was highly endowed with human, financial and technical capacity required to take up these adaptation strategies.

Further, the results revealed that most households employed multiple adaptation strategies to cope with climate variability and extreme events. This could be attributed to autonomous adaptations where farmers adopted unplanned adaptations to climate variability and extremes unconsciously. Interestingly, farmers detailed that most of the adaptations were learnt from fellow farmers and not from agricultural extension officers. The current trend of results is in agreement with findings of Fagariba *et al*. (2018) who found that farmers in Sissala West District in Northern Ghana had employed multiple adaptation measures in response to climate variability. This is also in line with findings of Ogallo (2014) who found that farmers in Soroti District, Eastern Uganda had employed quite a number of adaptation measures in response to the changing climate and variability.

Crop diversification was identified as an agricultural adaptation to climate variability and extremes in the four sub-locations (69.8%). To a large extent, crop diversification was found to guarantee good harvests. The cultivation of both short and long cycle crop varieties enabled the households to take advantage of the different maturing times of crops, to strengthen their resilience to impacts associated with variable unpredictable rainfalls and drier conditions, in order to increase chances of having good harvest during the drier and wetter seasons. Other farm level adaptation that were common within the four sub-locations included; mixed crop-livestock systems, planting drought resilient crops, implementing soil conservation techniques, changing planting time, using organic manure, improved crop variety, use of pesticides and agro-forestry. The result is in agreement with the findings of Paavola (2008) who found that farmers altered their mix of crops, switched between crops and changed planting dates as ways of adapting to the evidenced climatic variations. Similarly, findings of Kasirye (2010) revealed that farmers in Uganda used mixed cropping and diversification of crops as a form of insurance against rainfall variability and pests attack. The risk of complete harvest failure due to a climatic event such as drought, intense rainfall or high temperature spells, was reduced by having different crops in the same field or various plots with differing crops since not all crops and fields are affected the same way by such climate events (Kasirye, 2010).

5.3.1 Factors influencing farmers' adaptation to climate variability and extremes in Yuku, Kaveta, Kauwi and Kasaini sub-locations

Results of the logistic regression analysis showed that gender, education level, farming experience and age significantly ($p<0.05$)) influenced adoption of adaptation strategies to climate variability and extremes in the study areas (Table 4.15)

The results established that education level of the household head had a significant and positive influence on farmers' adoption of adaptation strategies to climate variability (coefficient=0.35, p= 0.00; odds ratio=1.24). The odd ratio indicated that farmers with high education level were more likely to adapt as compared to farmers with low education levels. This could be ascribed to the ability of household heads with high education levels to access and conceptualize information relevant in making innovative decisions. Additionally, households with high levels of education were flexible thus able to take up new adaptation strategies. In similar studies, Gbegeh *et al*. (2012) and Mutunga *et al*. (2018) also established that higher level of education leads to an increase in the adoption of adaptation measure and new technologies.

With reference to age, the current study established that age had a significant and positive influence on adoption of adaptation strategies in the study area (coefficient=1.02; p=0.00; odds ratio=1.02). The odds ratio for age implies that a unit increase in age of the household heads increased the probability of farmers to adapt to climate change by a factor of 1.02. This could be attributed to the ability of older farmers to critically assess and weigh adaptation strategies based on their vast farming experience thus making profound decisions on adopting particular strategies. The current trend of results is in consonance with findings of Mutunga *et al*. (2018) who found that older farmers had more experience in farming than younger farmers, hence a higher probability of adopting the adaptation measures. However, the results are contrary to Adesina *et al*. (1995) who found older farmers to be more risk-averse and less likely to be flexible than younger farmers and thus have a lesser likelihood of adopting new technologies.

The farming experience of household heads was also found to have a significant and positive influence of farmers' adoption of adaptation strategies to climate variability and extremes in the study areas (coefficient=0.01; p=0.01; odds ratio=1.02). This indicated that farmers with more farming experience were 1.02 times more likely to adopt adaptation strategies compared to those with less farming experience. Farmers who had been in agricultural holdings for longer year had better knowledge and information on changes in climatic conditions, crop and livestock management practices compared to those who had just started farming. The results are in agreement with findings of Ndungu and Bhardwaj (2015), Deressa *et al*. (2008), and Mutunga *et al*. (2018) who found that increase in farming experience increases the probability of adoption of climate change adaptation measures.

Gender had a positive and statistically significant influence on adoption of adaptation strategies (coefficient=0.66; p=0.04; odds ratio=1.93). Households headed by males were 1.93 times more likely to adapt to climate variability and extremes as compared to female-headed households (Table 4.15). Interestingly, women in the study areas had more farming experience and information on various management practices and how to change them based on available information, climatic conditions and other factors such as markets and food needs of the households compared to their male counterparts. However, the capacity of women to embrace labour-intensive climate adaptations and innovations was undermined as men were the household decision makers and property owners. The results are in consonance with findings of Gbegeh *et al*. 2012 who indicated that in many parts of Africa, women are often deprived of property rights due to social barriers. Consequently, they have fewer capabilities and resources than men (Gbegeh *et al*., 2012). The current result contradicts the findings of Gbetibouo (2009) who found that female-headed households were more likely to take up climate change adaptation measures. They reasoned 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.

Further scrutiny of the results revealed that, agro-ecological zone, access to credit facilities, access to extension services and access to early warning weather information, did not have a statistically significant influence on adoption of adaptation strategies to climate variability and extremes. Nevertheless, the study established that farmers with access to credit facilities were 1.49 times more likely to adopt adaptation strategies compared to those that did not have access to credit (Table 4.15). Poor access to credit facilities and borrowing capacity hampered any efforts by farmers to embrace adaptation strategies that required heavy investment such as irrigation buying of insurance, chemical fertilizers and aquaculture. This is in agreement with findings of Gbetibouo (2009) and Shiferaw *et al.* 2009 who found that under conditions of flawed credit, farmers will not adopt certain adaptation measures as adoption of new technologies required borrowed or owned capital.

Pertaining access to early warning weather information, the current study indicated that a unit increase in the number of sources of early warning weather information increased the probability of farmers adopting the adaptation strategies by a factor of 1.01 (coefficient=0.005; p=0.68; odds ratio=1.01). This implied that farmers with more sources of early warning weather information were more likely to adopt adaptation measures against climate variability and extremes. Access to climate information increased farmers' awareness and knowledge on the changing rainfall and temperature patterns as well as the possible climate variability response strategies making it easier for farmers to decide on viable adaptation strategies. A study by McBride & Daberkow (2003) revealed that certain information sources can be more effective change agents than others and various information sources can influence the probability of adoption differently. Similarly, different sources of information become influential during different stages of adoption process. The present results are in line with findings of Mutunga *et al*. (2018) who indicated that farmers with access to climate information were more likely to adopt climate variability adaptation measures as compared to farmers without access to climate information.

The number of times of accessing extension services negatively influenced adoption of the adaptation strategies (coefficient=-0.038; p=0.63; odds ratio=0.96). This implied that, farmers with little or no access to extension services were more likely to adopt adaptation strategies than farmers with adequate access to the services. Personal observations and interactions with farmers suggested that farmers in the study area did not rely on extension service providers for information and implementation of adaptation strategies. Majority of farmers adopted planned or autonomous adaptation strategies once they perceived changes in precipitation trends and temperature regimes regardless of whether the county government provided extension services or not. The results contrast the findings of Gbetibouo (2009) who found that farmers with access to extension services are likely to have information about climate and weather changes thus more knowledge on how to carry out adaptation strategies.

Both on-farm income and off-farm income did not have a significant influence adoption of adaptation strategies (coefficient=-0.00; p= 0.44; odds ratio=1.00; (coefficient=-0.00; p= 0.77; odds ratio=1.00 respectively). However, the odds ratios implied that, unit increase in on-farm and off-farm income increased the probability of farmers to adopt adaptation strategies by a factor of 1. As expected, households with higher income had the ability to take up adaptation strategies that needed capital investment unlike households that had low income endowments. On-farm income was nonetheless less reliable in influencing adoption of adaptation strategies as it is affected by climate variability thus enhancing risk bearing capacity by farmers. Other studies have established that asset endowments and wealth have a significant influence on the ability of smallholder farmers to adopt certain technological practices (Nkonya *et al*., 2008; Gbetibouo, 2009). The current results also agree with findings of Shiferaw *et al*. (2009); Ndung'u and

Bhardwaj (2015) and Mutunga *et al*. (2018) who found that 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.

Pertaining to agro-ecological zone background, the results revealed that the zones did not have a statistically significant influence on adoption of adaptation strategies (coefficient=-0.060; p= 0.77; odds ratio=1.06). However, the probability to adopt adaptation strategies increased by a factor of 1.06 in semi-humid areas (Kaveta and Kauwi sub-locations) compared to the arid areas (Kasaini and Yuku sub-locations). This could be attributed to proximity to town and County head offices thus more opportunities; improved socio-economic characteristics such as education level, monthly income, savings and trainings attended by family members in the semi-humid areas compared to the arid areas. The findings contradict studies by Mutunga *et al*. (2018) who found that farmers in semi-arid areas had a higher probability of adopting adaptation measures to climate variability compared to those in semi-humid areas.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The present study established that farmers in arid agro-ecological zone were the most vulnerable to climate variability and extremes while those in semi-humid zone were the least vulnerable. This was as a result of the arid agro-ecological zone experiencing higher potential impacts along with lower adaptive capacity while the semi-humid zone experienced lower potential impacts coupled by higher adaptive capacity. The study revealed that biophysical elements determining exposure and sensitivity to climate variability and extremes like the climate related natural disasters were beyond the immediate influence of the policy makers. Therefore, amongst the three components of vulnerability, adaptive capacity was found to have direct policy implications. Further, improving the adaptive capacity also had indirect implications on improving the sensitivity of the farmers. For instance, creating opportunities for off-farm income (human asset) reduces the dependence of the households on natural resource-based livelihoods, thereby reducing their sensitivity towards climate variability and extremes.

Most farmers had embraced multiple adaptation strategies to climate variability and extremes. The most common adaptation strategies adopted by the farmers included; use of organic manure, change of planting time, mixed crop and livestock system, use of pesticides, crop diversification, planting drought resistant crops, agro-forestry and use of improved crop variety. The study results showed that gender, education level, farming experience and age significantly influenced farmers' adoption of adaptation strategies to climate variability and extremes in the study areas. However, the fact that most farmers had taken up adaptation strategies to climate variability and extreme events did not necessarily mean that those adaptations were appropriate and effective in building resilience at the local contexts. While farmers in the study area had for a long time developed local adaptation strategies to cope with erratic environmental shocks, increased climate variability and extreme weather events had exceeded the present coping range and adaptive capacity particularly in the arid areas.

6.2 Recommendations

The following interventions are needed to create conditions that will enhance farmers' adaptive capacity and enable households as well as individual farmers to take up appropriate adaptation strategies. The interventions focus on strengthening resilience and reducing vulnerability of farmers in in arid, semi-arid, semi-humid and transitional zones from semi-arid to semi-humid agro-ecological zones to climate variability and extremes.

i. Farmers should unleash the off-farm livelihoods options, which will not only improve their cash income, but also reduce their dependence on natural resources thus reducing their vulnerability to climate variability and extreme events.
ii. The County and National Government should team up with NGOs such as Red Cross to provide reliable post-disaster relief measures, maintain buffers (like food stores), establish early warning systems, and evacuation centres particularly in arid zones in order to reduce farmers' sensitivity to climate variability and extreme events.
iii. The County government of Kitui should collaborate with the National government and NGOs to construct all-weather roads linking the rural settlements to the nearest market centres. This will improve farmers' access to inputs, information, and off-farm employment opportunities thus improving their adaptive capacity.
iv. There is a need to recognize and involve farmers through their local groups in adaptation planning at the County level in order to meet the needs of farmers through viable adaptation strategies.
v. Governmental and non-governmental agencies should join forces to mainstream adaptation to climate variability and extreme events into programs in different sectors (agriculture, environment, health, industry, water and land) as a crosscutting concern.
vi. Further study is recommended to ascertain the weights of the components of vulnerability and their individual indicators in determining the overall vulnerability of farmers in different agro-ecological zones in Kitui.

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APPENDICES

APPENDIX 1: SAMPLE QUESTIONNAIRE

HOUSEHOLD SURVEY INTERVIEW SCHEDULE ON HOUSEHOLD LEVEL VULNERABILITY TO CLIMATE VARIABILITY AND EXTREMES

Kindly respond to all the questions honestly and faithfully as they apply to your farm. The intended study is purely for research purpose and therefore your responses will be treated with strict confidentiality. Answering all the questions will be greatly appreciated.

Enumerator's Name: ______________________ Date of interview: _______/____/____
Time when the interview started: ___________ End: ___________________________
Sub-County: __________________Ward: ______________ Location: _________________
Sub-Location_____________ Village: ____________________
Coordinates: N______________________________S____________________________

1.	Name of the Respondent? Preferably the household head_______		
2.	Contact (Mobile)		
3.	Gender of the respondent_________	1=male, 2=female	
4.	Age of the respondent_______		In years
5.	What is your relationship with the household head?___________	1=Household head, 2=Spouse of the household head, 3=Grown up child, 4=Relative, 5=Others (Specify)	
6.	Name of household head (main decision maker on farm operations) _____________		
7.	Gender of the Household head_____	1=male, 2=female	
8.	Age of household head____		In years
9.	Marital status of the household head ________________	1= Single 2=Monogamously married 3=Polygamously married, 4= Divorced/ separated 5= Widowed	

10.	Education level of household head_____	1=none, 2=primary, 3=secondary, 4=College 5=University 6=Others (specify)	
11.	Main occupation of the household head __	1=full-time farmer, 2=Business 3=Casual laborer 4= Formal employment 5=Others (specify)	
12.	What is the Main source of labor in the farm? ______	1=family labor, 2=hired labor, 3=other (specify)	
13.	Are you a member farmers group?	0=No, 1=Yes	
14.	If yes is the group registered?	0=No, 1=Yes	
15.	What is the total land size owned (here and elsewhere) _______?		(In acres)
16.	How many years has this household been involved in farming on this piece of land? ___		Give the number of years e.g. 10
17.	What is the land acreage under irrigation during dry spells? ________		(In acres)
18.	What is your approximate annual income from farm produce (surplus sold) ______		Indicate the amount
19.	What is your approximate off farm annual income ________		Indicate the amount
20.	Do you have access to credit?	Yes=1, 2=No	If No go to 22
21.	How much loan did you borrow in the past one year? _________		Amount (Ksh)
22.	What is your type of farming activity?	1) Livestock (2) Crop (3) Mixed (4) Others (Specify)	
23.	Have you noticed any significant changes in weather	0=no, 1=yes	

	patterns over the years in relation to agricultural water availability?		

	VULNERABILITY TO CLIMATE VARIABILITY AND EXTREMES

Exposure

24. What is your perception on frequency and number of incidents of the following disasters in the last 10 years?

Disaster	**Frequency**			**Estimated number of incidents in the last 10 years**
	Increased	**No change**	**Decreased**	
Floods				
Droughts				
Storms/strong winds				
Wild /forest fires				
Livestock diseases				
community inter-border conflicts				
Human -wildlife conflict				
Total				

Sensitivity

25. Have the disasters (drought, floods, wild/forest fires, livestock diseases and conflicts (community inter-border conflicts or human-wildlife) affected any of the following in the last ten years?

Extreme event	Human		Cows		Goats		Sheep		Others		Total
Floods	Dead	Injured	Dead	Injured	Dead	Injured	Dead	Injured	Dead	Injured	
Droughts											
Storms/strong winds											
Wild /forest fires											
Livestock diseases											

community inter-border conflict											
Human - wildlife Conflict											
Total											

26. Have the disasters (drought, floods, wild/forest fires, livestock diseases and conflicts (community inter-border conflicts or human-wildlife) damaged any of the following in the last ten years?

Extreme event	Trees (acre/number	Crops (acres)	Productive land (acres)	Road (Km)	House (Number)	Others
Droughts						
Storms/strong winds						
Wild /forest fires						
Livestock diseases						
Conflicts						
Total						

27. What is your perception on trend of quantity of water in following water resources in the last ten years?

Water resource	**Trend in water quantity**			**Estimated number of times it has dried up in the last ten years**
	Increased	**No change**	**Decreased**	
River/stream				
Bore hole				
Shallow well				
Spring				
Earth/sand dam				
Water pan				
Other (specify)				

28. Give an estimate of your household income in the following:

Income structure	**Tick**	**Estimate per year/12 months (Kshs.)**
Natural resource-based Income		
Farm wages/ Earnings from Crops		
Livestock production		
Honey Sales		
Forestry products		
Sand harvesting		
Others (specify)		
Total		
Non-natural based income		
Salaried jobs		
Remittances		
Skilled non-farm jobs e.g. masonry, carpentry, handcraft, mechanic		
Small business returns		
Others (specify)		
Total		

29. Adaptive Capacity

Component Indicators	**Guiding questions**	Number
Physical Assets	Indicate the number of gadgets owned and used in accessing the information	
	Indicate the number of time you accessed extension services in last 1 year	
	Indicate the number of sources of timely early warning weather information	
	Distance in Km to the nearest motorable road	
	Distance in Km to the nearest market	
	Distance in Km to the nearest Water source	

	Distance in Km to the nearest health facility	

Human Assets	Highest level of education of qualification in the family	Level	Number of schooling years
		None Primary High School College Graduate Post Graduate	
	Number of persons in the HH having salaried employment?	Indicate the number	
	Trainings or vocational course attended by family members	Indicate the number	
Natural Assets	Size of productive land in acres	Size in acres	
	Size of unproductive land in acres	Size in acres	
	Do you have bullock Small stock (includes goats and sheep Large stock (includes cows, camels, donkeys	Indicate number	
Financial Assets	What is the estimated Gross household income per month?	________________Kshs	
	What is the estimated household savings per month?	_______________________Kshs	
Social Assets	Are you a member of any community-based organization? Yes [ ] No[ ] Are you a member of any cooperative society?	Indicate number	

	Yes[ ] No[ ]	
	Indicate the number of credit facilities accessed in the last five years	

	ADAPTATION TO CLIMATE VARIABILITY AND EXTREMES

30. Which of the following adaptation strategies have you adopted in your HH in response to the changing climate?

Adaptation Options	**Adopted? Yes or No**
Shift from livestock keeping to crops farming	
Mixed crop livestock system	
Crop diversification	
Plant Drought resilient crops	
Build a water-harvesting scheme	
Practice reuse of water	
Crop diversification	
Planting drought tolerant varieties	
Changing planting time	
Implement soil conservation techniques	
Buy insurance	
Put trees for shading	
Irrigation	
Change from crop to livestock	
Reduce number of livestock	
Increase livestock diversity	
Use animal feeds supplements	
Migrate to urban area	
Find off-farm job	

Lease your land	
Use of chemical fertilizer	
Use of organic fertilizer (manure)	
Use minimum tillage	
Use improved crop varieties	
Use of inorganic fertilizer	
Use of pesticides	
Agro-forestry	
Integrated pest management	
Seeking support from veterinary officers	
Move herd from one place to another	
Do you feel that you have adequately adapted?	

APPENDIX 2: BUDGET

S/NO	ITEM	DETAILS	TOTAL COST
	Stationery	Biros, Pencils, Rubbers and note book	2000
2	Production of questionnaires	Printing and photocopying	5000
3	Flash drive	One	1700
4	Airtime and internet		5000
5	Transport and accommodation	Two way	28, 000
	Publication	Two	20000
6	Meals	Tea and lunch	10000
7	Research assistants	Three	25000
7	Printing of thesis for marking	Three	2000
9	Printing of final thesis	Three	7000
	Total		105700

APPENDIX 3: WORK PLAN

Duration: September 2018-February 2020								
	2018			**2019**			**2020**	
Activity	**May-June**	**July-September**	**October-December**	**January-April**	**May-September**	**November**	**Jan-uary**	**February-March**
Proposal development	■							
Research proposal revision, defence and submission		■						
Testing instruments for data collection.			■					
Actual data collection				■				
Data analysis, interpretation and reporting					■			
Seminar						■		
Submission of the research report							■	
Thesis defence and Publication								■