VULNERABILITY ASSESSMENT OF MAASAI PASTORALISTS UNDER CHANGING CLIMATIC CONDITION AND THEIR ADAPTATION STRATEGIES IN KAJIADO COUNTY, KENYA

Bobadoye, Ayodotun Oluwafemi

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DECLARATION

I declare that this Thesis is my original work and has not been submitted for the award of a degree in any other university. Where other people's work has been used, this has properly acknowledged and referenced in accordance with the University of Nairobi's requirements.

BOBADOYE Ayodotun Oluwafemi
Reg. No. I85/90701/2013

Signature ______________________________ Date ____________________

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

Prof. William O. Ogara
Institute for climate change and adaptation
University of Nairobi

Signature ___________________________ Date _____________________________

Dr. Gilbert O. Ouma
Institute for climate change and adaptation
University of Nairobi

Signature ___________________________ Date _____________________________

Dr. Joshua O. Onono
Institute for climate change and adaptation
University of Nairobi

Signature ___________________________ Date _____________________________

DEDICATION

This work is dedicated to Almighty God, my ever present help. To my wife and best friend Bridget Bobadoye for her unflinching support, my parents Mr. and Mrs. Bobadoye for guiding me in the path of truth and finally to my lovely child Oluwasindara Bobadoye.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Human adaptive responses to climate change occur at the local level, where climatic variability is experienced. Therefore understanding adaptive strategies at the local level is important in planning effective adaptation options in semi-arid environment. This study was therefore conducted to assess household vulnerability and adaptation strategies of Maasai pastoralists to climate change and variability in Kajiado County.

Transdisciplinary research approach was used to analyse the perception of Maasai pastoralist to climate change and variability; measure pastoralist vulnerability at the household level and evaluate their adaptation strategies to climate change and variability.

Primary data was collected using focus group discussions, household survey using questionnaire and key informant interviews. A total of 305 household interviews and 30 key informant interviews were conducted. Secondary rainfall and temperature data for 43 years (1970-2013) obtained from Kenya Meteorological Service was also analyzed. Data was analyzed using statistical package (R) software, and vulnerability maps showing the vulnerability level of communities in the study areas were produced using ArcGis 10.2 GIS software.

Results showed that Kajiado County has a bi-modal rainfall pattern with two distinct rainy seasons. Ngong (Kajiado north) had the highest average annual rainfall of 979.2mm, followed by Mashuuru (Kajiado central) 674.50mm, Isinya (Kajiado east) 612.6mm and least for Magadi (Kajiado west) 450.60mm. The results revealed a high level of spatial and temporal variability in rainfall trend in Kajiado County. The results showed that a rise in minimum temperature (1.41^0C), maximum temperature (0.47^0C) and average temperature (0.94^0C) occurred in the study area between 1970 and 2013. The study identified drought as the main climatic extreme event in the study area. The standardized precipitation index (SPI) results showed increase in drought occurrence in Kajiado County in the recent years, with six years (2000, 2003, 2004, 2007, 2008 and 2011) having negative SPI values from 2000-2011. The year 2000 was the driest year recorded, with an SPI value of -3.09. Results further showed that Maasai pastoralist perceptions on temperature change and years of drought in the study area tally with evidence from Kenya meteorological service.

Vulnerability analysis showed that gender of household head, years of experience in the area, educational level, visit by extension agents, herd size, livestock diversity, credit access, land size and livestock mobility had significant influence on vulnerability of households in the study area. The study further revealed that Kaputiei North with high population density had the highest number of highly vulnerable households (33%), followed by Oloosirkon (19%), Kitengela and Imororo had (15%), while Kenyawa-Poka had the least percentage of highly vulnerable households (5%). The vulnerability map showed variation in the levels of vulnerability of households even within the same community. The study observed a direct correlation between vulnerability and availability of basic amenities in rural areas in Kajiado County. Maasai pastoralists are already taking measures such as rain harvesting, livestock diversity, early warning system and mobility to adapt to climate extremes. However, increase in drought occurrence in the last few years is reducing their resilience.

The study recommends collaboration among stakeholders and integration of various sources of knowledge in addressing climate change and variability among pastoralists in Kajiado County. Efficient early warning system using technologies such as mobile phones and community radio for climate information dissemination, rapid infrastructural development and efficient disaster management are no regret adaptations options that will reduce vulnerability of rural pastoral communities to climate change and variability.

DEFINITION OF KEY TERMS

The definition of some terms (such as vulnerability, adaptation, and climate change etc.) used in this thesis is necessary because they may sometimes have varying definition depending on the context of use. The definition of commonly used terms in this thesis are provided by (Intergovernmental Panel on Climate Change, 2001; 2007; 2012; 2014) and supported with alternative definition where applicable as follows:

Adaptation: Adjustment in ecological, social or economic system in response to actual or expected climatic stimuli and their effects to moderate or offset potential damage or take advantage of opportunities associated with change in climate.

Adaptive capacity: This is the ability of a system to adjust its characteristics in order to expand its range under existing climate variability and future climate change.

Climate change: Climate change is a significant change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. Climate change may be a change in average weather conditions, or in the distribution of weather around the average conditions (i.e., more or fewer extreme weather events)

Climate variability: Refers to variations in the mean state and other statistics (such as standard deviation, occurrence of extremes, and others) of climate at all spatial and temporal scales beyond that of individual weather events.

Dry lands: Refers to all terrestrial regions where the production of crops, forage, wood and other ecosystem services is limited by water, which encompass all lands where climate is classified as dry-sub-humid (aridity index 0.50-0.65), semi-arid (aridity index 0.20-0.50) and arid (aridity index 0.05-0.20).

Exposure: This is used to refer to the presence (location) of people, livelihoods, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected by physical events and which, thereby, are subject to potential future harm, loss or damage.

Extreme events: Refers to the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends (‘tails’) of the range of observed values of the variable.

Mitigation: Climate change mitigation refers to efforts to reduce or prevent emission of greenhouse gases.

Perception: It is the process by which we receive information or stimuli from our environment and transform it into psychological awareness.

Resilience: The ability of a system to anticipate, absorb, accommodate or recover from the effect of a hazardous event in a timely and efficient manner, including through ensuring preservation, restoration, or improvement of its essential/basic structures and functions.

Risk: This refers to the interaction of physically defined hazards with the properties of the exposed systems. Risk equals the probability of climate hazard multiplied by a given system's vulnerability.

Sensitivity: The degree to which a system is affected or responsive to climate stimuli.

Vulnerability: The degree to which a geophysical, biological and socioeconomic system are susceptible to, and unable to cope with adverse effect of climate change including variability and extremes.

ACRONYMS AND ABBREVIATIONS

AEZ	-	Agro-ecological zones
ASL	-	Above sea level
ASALs	-	Arid and semi arid lands
AU	-	African Union
CBO	-	Community Based Organization
CBS	-	Central Bureau of Statistics
ENSO	-	El Nino Southern Oscillation
FAO	-	Food and Agricultural Organization of the United Nations
FGD	-	Focus group discussion
GCM	-	Global Circulation Model
GDP	-	Gross Domestic Product
GHG	-	Greenhouse gases
GIS	-	Geographic information system
GOK	-	Government of Kenya
HVI	-	Household Vulnerability Index
ICPAC	-	IGAD Climate Prediction and Application Centre
IGAD	-	Intergovernmental Authority on Development
ILRI	-	International Livestock Research Institute
IPCC	-	Intergovernmental panel on climate change
ITCZ	-	Inter-Tropical Convergent Zone
KMS	-	Kenya Meteorological Service
NDMA	-	National drought management authority
NGOs	-	Non-Governmental Organization
PCA	-	Principal component analysis
PRA	-	Participatory rural appraisal
ROK	-	Republic of Kenya
SEI	-	Stockholm Environment Institute
SPI	-	Standardized Precipitation Index
SST	-	Sea Surface Temperature

UNDP	-	United Nations Development Programme of the United Nations
UNEP	-	United Nation Environmental Programme of the United Nations
UNFCCC	-	United Nations Framework Convention on Climate Change
USAID	-	United States Agency for International Development
WFP	-	World Food Programme
WWF	-	World wide fund for nature

CHAPTER ONE

INTRODUCTION

1.1 Background

Climate change is defined as a significant and measurable change in the statistical distribution of weather patterns over periods ranging from decades to millions of years (IPCC, 2014). It may be a change in average weather conditions, or in the distribution of weather around the average conditions. The change in global climate as shown in figure 1.1 has been reported to have severe effect on environmentally based livelihoods in many areas of the world (Omolo, 2010). The adverse effects of climate change include increased frequency and intensity of storm, thunder, flood, drought and hurricanes. All these are having severe effect on human livelihood, causing poverty, malnutrition and reduced agricultural productivity (Ayanda, *et al*., 2013).

Countries in Africa are likely to be the most affected by climate change. This is due to limited capacity for disaster management, limited financial resources and weak institutional capacity in most African countries (Rockstrom, 2008). Moreover, majority of the population survives on rain-fed agriculture, which makes them more vulnerable (IFPRI, 2004). In the East African region, the increase in the gap between population growth and agricultural capacity is exacerbating the already declining food security and increasing vulnerability.

The impact of drought appears to have become more severe in recent years in East Africa (Funk *et al*., 2008). Although East African pastoralists have historically coped with seasonal and annual climatic variability, their rainfall-dependent livelihoods are especially vulnerable to the long-term climatic changes projected for the region (Kirkbride and Grahn 2008). What is obvious is that climate change is impacting on the physical and biological systems (Rozenzweig *et al*., 2008). However, little information exists on household vulnerability to climate change and variability. Analyzing household vulnerability to climate change and understanding their adaptation strategies is necessary for adaptation planning and resource allocation in the rural areas where climate change impact is most felt.

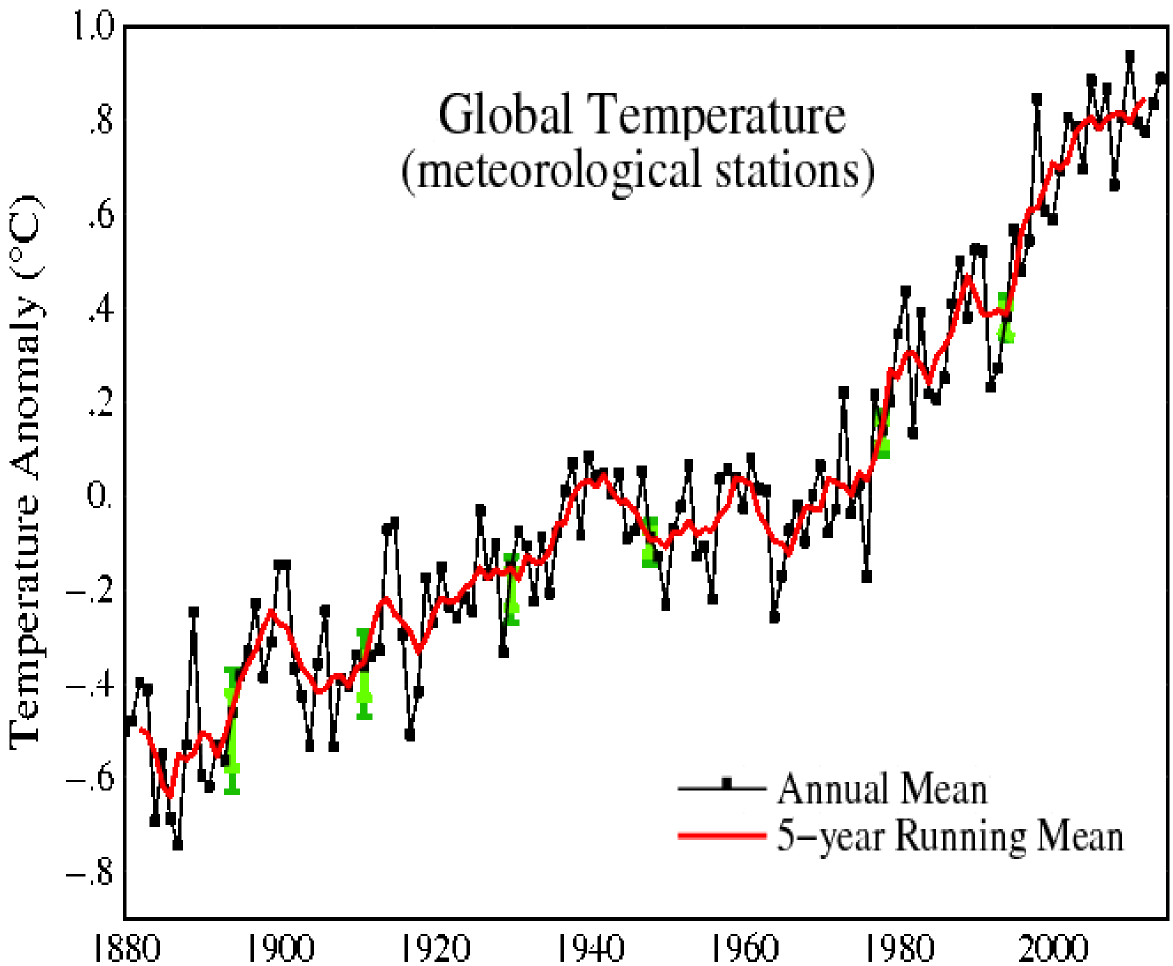

Figure 1.1: Global temperature change from (1880-2000)

Source: IPCC 2007

More than 80% of Kenya, particularly areas around the northern parts receive around 500mm of rainfall per year, and are classified as arid and semi-arid lands (ASALs) (GOK, 2005). About 12 million Kenyan people, which are almost a third of the whole population, live in these areas. Livestock production (largely through Pastoralism) is the main source of livelihood in most areas in the ASALs of Kenya. Livestock serves many roles in pastoral society: both as means and outcomes of production, sources and objects of labour, values, and social, cultural and capital goods (Galaty and Johnson, 1990). Livestock production accounts for 26% of total national agricultural production in Kenya. Over 70% of the livestock and 75% of wildlife in Kenya are in the ASALs (GOK, 2005). Increase in extreme climatic events such as drought and dry spell is having severe effect on pastoralist livelihood in the ASALs of Kenya.

The Maasai people live in southern Kenya and northern Tanzania along the Great Rift Valley on semi-arid and arid lands (Orindi *et al*., 2007). The Maasai occupy a total land area of 160,000 square kilometers and have a population of approximately 1.5 million people. The Maasai depend on livestock such as cattle, goats and sheep as their primary source of income. Livestock serves as a social utility and plays an important role in the Maasai economy. The population of the Maasai is high in the Kajiado district in Kenya, which borders the capital Nairobi to the north and Tanzania to the south. Increase in drought occurrence coupled with population growth and sedentary lifestyles especially in Kajiado County have made the Maasai more vulnerable to climate variability and change (Orindi *et al*., 2007).

Vulnerability is a concept widely used by different fields of specialization. The definition of vulnerability is based on the field of study and the context of use (Fussel, 2007). Vulnerability is commonly defined as the tendency or predisposition to be adversely affected. It has been studied as a function of adaptive capacity, sensitivity and exposure to hazards (Adger and Kelly 1999; Kelly and Adger 2000; Paavola 2008; Yuga *et al*., 2010). IPCC (2014) defines vulnerability to climate change as "the degree to which a system is susceptible to and unable to cope with adverse effect of climate change including climate variability and its extremes". Vulnerability is a function of character, magnitude and rate of climate change and variability to which a system is exposed to, its sensitivity and its adaptive capacity. Adaptive capacity is the ability of people to cope with changing context and is explained by socio–economic indicators. Sensitivity is the ability of a system to be affected and exposure is the incidence of extreme climatic event (Kasperson *et al*., 1995; Paavola, 2008).Vulnerability to climate change can be analyzed at global, regional, national and local level (Brooks 2004; Deressa *et al*., 2008; IPCC 2014).

Adaptation to climate change is defined by IPCC (2014) as the "adjustment in ecological, social or economic system in response to actual or expected climatic stimuli, and their effects to moderate or offset potential damage or take advantage of opportunities associated with change in climate". The adaptation process includes three essential stages

(1) vulnerability assessment (2) capacity building and (3) implementation of adaptation options. Pastoral households and their communities in ASALs have indigenous ways of adapting to varying degree of extreme weather events. Recent increase in the frequency of occurrence of these extreme weather events such as drought is stretching the resilience of the pastoral community and having severe effect on the pastoralist livelihood in the arid and semi-arid areas of Kenya. The proportion of household vulnerability to extreme weather events is increasing in Kajiado County in Kenya. There is an uncertainty to the degree to which the population or the system is becoming susceptible and unable to cope with climate related hazards and extreme events. Research on vulnerability and adaptation strategies of Pastoralist in Kajiado County is therefore important for adaptation planning and decision making in the County.

1.2 Problem statement

The arid and semi-arid lands have been identified as the most vulnerable areas to climate related risks in Kenya. Climate change has severe impacts on livestock production, small-holder agriculture and tourism, which are the dominant sources of livelihoods in ASALs. There is a strong link between climate and livelihoods in the ASALs and majorities of the population are heavily dependent on rainfall for the various land-use practices. As a result, rural livelihoods and food security in the ASALS of Kenya are highly vulnerable to climate variability (WWF, 2006).

Pastoralism plays a crucial role not only in the economies of the practicing societies, but also in the national economy as a whole. About 75% of livestock are found in the ASALs of Kenya, and the sector is estimated to contribute about 13% of Kenya's GDP, 40% to agricultural GDP and it also employs 50% of the labour force (FAO, 2010; Orindi *et al.*, 2007). Maasai Pastoralists in Kenya have practiced transhumance which was made easy by the abundance of land in ASALs. This made pastoralism an efficient way of utilizing these large tracts of land while maintaining its productivity through seasonal balancing of graze/browse thereby giving time for vegetation regeneration. This has made the system in-tune with the ecological realities of ASALs where rainfall and grazing are subject to high risk of seasonal variability. This practice is however becoming less sustainable as forage easily succumbs to forces of climate variability and change.

Climate change and variability has exposed pastoralists, their herds and ecosystem to risk associated with increased frequency of extreme climatic events such as droughts and flood (Birch and Grahn, 2007). The 2008-2009 and 2010-2011 widespread droughts in the Horn of Africa resulted in the loss of approximately 60-70% of livestock by pastoralists living in ASALs of Kenya, and about 3.2 million people were left in need of emergency assistance in the region (Amwata, 2013). High livestock mortality has devastating effects on livelihoods of pastoralists (Huho and Kosonei 2014). Livestock is an integral form of pastoral capital; it functions as a means of transfer of food and wealth, and act as an insurance against weather risk such as drought (Behnke and Muthami 2011).

Amwata (2013) reported that famine has become increasingly common since 1990s and is undermining food security in entire ASALs of Kenya. Further, the negative effects associated with climate change and variability is compounded by many other factors, including widespread poverty, violent conflicts, livestock disease outbreaks and land degradation. The increasing population growth which is projected to double the demand for food, land, water and forage resources in the near future is also a contributing factor that is increasing vulnerability of people living in the ASALs of Kenya (Davidson *et al.* 2003).

Climate change vulnerability analysis ranges from local level to the global level (Deressa *et al*., 2008; IPCC 2014). Over the last few decades, most of scientific literatures on vulnerability have concentrated on contributing to theoretical insight or measurement at the regional, national or global levels with selected indicators for each country or region (Hinkel, 2011). Yet, micro level vulnerability analysis is an essential pre requisite for local level planning and prioritization of resilience planning and strategies especially among communities at risk of projected climate variability and change (Callaway 2004; Fraser *et al*., 2011). Therefore, this study analyzed climatic data to determine the climate trend in Kajiado County and compare it with the perceptions of the Maasai pastoralist on climate change. The study conducted a micro level vulnerability assessment of Maasai communities in Kajiado to climate variability and change, mapping out the levels of vulnerability of Maasai households in the county. The study evaluated the present coping and adaptation strategies of Maasai pastoralist communities to climate change and variability in the study area. Finally the study integrated both indigenous and scientific knowledge in suggesting viable and sustainable no regret adaptation options to climate change and variability in Kajiado County Kenya.

1.3 Justification and Significance of the study

Shift in seasonal characteristics as a result of climate change and variability places an additional strain on food security, water availability and viability of the livelihoods of the Maasai communities in the ASALs. It is apparent that the livelihoods of pastoralist in ASALs of Kenya are directly linked to climate change and variability.

Many studies (Ndesanjo, 2007; Omolo, 2010; Orindi *et al*., 2007 and Amwata, 2013) have been conducted on the vulnerability and adaptation of Maasai pastoralist to climate change. Orindi *et al.* (2007) focused on the effect of drought on pastoralist livelihood; Amwata, (2013) analyzed the interplay between land use, climate change and livelihood and other studies focused on measurement of vulnerability indices at the national and regional level (Thornton *et al*., 2006; Opiyo, 2014). However, there is dearth of studies concentrating on a comprehensive vulnerability mapping of pastoralist communities in Kajiado County that can guide in decision making and resource allocation. Deressa *et al*., (2008), Pearson *et al*., (2008) and Sherwood (2013) reported that vulnerability contexts are diverse for different multiple spatial scales. This study developed a comprehensive vulnerability map using GIS for the pastoralist community in Kajiado County which will be useful for targeting interventions, priority setting and resource allocation at the micro level. The study also used transdisciplinary research approach to identify viable and acceptable adaptation strategies that will enhance the adaptive capacity of the pastoralist communities to climate change and variability

1.4 Objectives

The overall objective is to assess the vulnerability of Maasai pastoralist communities to the impact of climate change and variability in Kajiado County and present viable ways of enhancing their adaptive capacity.

The specific objectives of the study were to:

(1) Analyze the climate trend for the study area in Kajiado County.

(2) Determine the perception of Maasai pastoralists to climate change and variability in Kajiado County.

(3) Assess vulnerability of Maasai pastoralist communities to the effects of climate change and variability.

(4) Investigate pastoralist communities adaptation and coping strategies, and identify viable adaptation options to climate change and variability among the Maasai communities.

1.5 Research questions

This study is guided by the following questions:

- Is there meteorological evidence of climate change and variability in Kajiado County?
- What is the perception of Maasai pastoralist to climate change and variability?
- If the climate in Kajiado County is changing, what is the level of vulnerability of Maasai communities to climate change and variability?
- Which adaptation strategies are suitable for enhancing resilience of Maasai communitiesto the effect of climate change and variability?

1.6 Organization of the study

The organization of the study is presented in (Figure 1.2). The thesis is presented in Nine (9) chapters. Chapter one presents the general background and explains the problem the study sought to address. The chapter also explains the research questions, objectives, justification and significance of study. Chapter two contains a detailed literature review of the concept of climate change and variability. The chapter reviewed the impacts of climate change and variability on Africa, focusing on Kenya especially the ASALs. It also reviewed the concept of vulnerability and adaptation to climate change and variability. Chapter two further explains transdisciplinary research approach and its importance in climate change research. Chapter three presents a detailed description of the study area. The chapter provided detailed information on biophysical features and demographic features in the study area. The methodology of the research is presented in chapter four. The chapter described the process involved in data collection, data processing and data analyzes. Chapter five analyzed the trend of climate parameters (rainfall and temperature) in Kajiado County. The chapter presents spatial and temporal comparative analysis of rainfall trends in different sub-counties in Kajiado County from 1970-2013. The study also analyzed the change in annual temperature in the study area from 1970-2013. The chapter further presented the drought pattern in Kajiado County. Chapter six presented the perception of Maasai pastoralist to climate change and variability in Kajiado County in the last 30 years. The chapter also reported the indigenous knowledge of pastoralist on climate change. Chapter seven analyzed the household vulnerability of Maasai pastoralist to climate change and variability. Maps showing the levels of vulnerability of households and communities in the study area were also produced in the chapter. Chapter eight investigated the adaptation strategies and challenges of Maasai pastoralist communities to climate change and variability. The chapter provided possible ways of enhancing the adaptive capacities of Maasai pastoralist to climate change and variability in Kajiado County. The conclusion and recommendations of the study was presented in Chapter nine (9). The chapter also provided recommendations for further research.

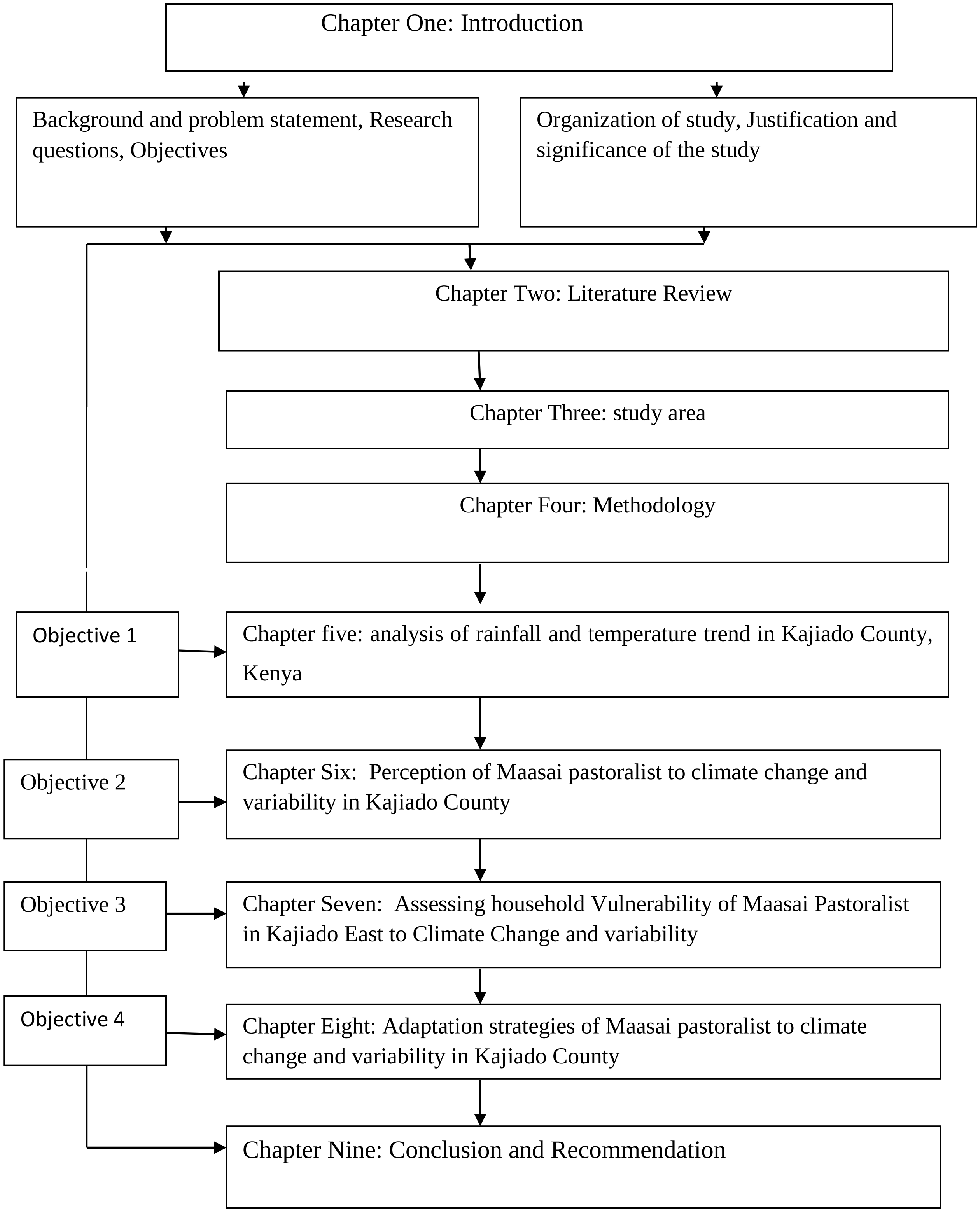

Figure 1.2: Organization of the thesis

CHAPTER TWO
LITERATURE REVIEW

2.1 Climate change and variability

Climate change and variability is emerging as one of the most serious global challenge. It is considered to be one of the most severe threats to sustainable development with severe impacts on the environment, human health, food security, economic activities, natural resource management and physical infrastructure (Hulme et al., 2001; Nicholson, 2014). IPCC (2014) defined climate change as any change in climate over time, whether due to natural variability or human activity. According to UNFCCC (1992), climate change is “the change in climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods”.

Climate variability also has been defined as “variations in the mean state and other statistics (such as standard deviation and the occurrence of extremes) of the climate on all temporal and spatial scales beyond that of individual weather events” (IPCC, 2007). Indicators of climate variability include extended droughts, floods, forest fire, cyclones and conditions that result from periodic El Niño and La Niña events. Climate variability reveals year to year variations of climatic elements such as temperature and rainfall at several time scales (Tasokwa, 2011; Amwata, 2013). Variability includes variation that may result from natural internal processes within the climate system (internal variability) or variations as a result of external or anthropogenic forces (external variability) (Tasokwa, 2011). There is a fundamental difference between climate variability and climate change. Climate change constitutes a shift in meteorological conditions that last for a long period of time, from decades to centuries, while climate variability is a short-term fluctuation happening from year to year.

According to IPCC (2007) the warming of the climate system is unequivocal, as is now evident from observations of increases in global average temperature and ocean temperatures. Climate change is also evident in widespread melting of the snow and ice, and rising global average sea levels. In addition to these relatively gradual changes, climate change also has impacts in the form of more weather related disasters such as increased tsunamis, drought and floods. Existing literature on climate change attributes rise in global temperature to increase in emission of greenhouse gases (carbon dioxide, methane, nitrous oxide, hydro-fluorocarbons and others) produced by human activities (Hulme *et al.* 2001). Although the Earth's atmosphere naturally contains greenhouse gases, it is believed that industrialization in the last millennium led to massive emission of green house gases especially carbon dioxide into the atmosphere. This increased emission of greenhouse gases is causing anthropogenic greenhouse effect that leads to climate change (IPCC, 2014). Anthropogenic emissions of carbon dioxide account for about 63% of the greenhouse gas warming effects in the long-term and for 91% in the short-term (IPCC, 2014).

2.2 Climate change in Africa

The climate of Africa is naturally both highly diverse and highly variable. It encompasses the extreme dry areas of the Saharan deserts at one end to the extreme humid lands of the Congo rainforest at the other (Christensen et al., 2007). The continent of Africa has the largest tropical area in the world. The equator runs through the middle of Africa, and about 90 per cent of the continent lies within the tropics. Climate in Africa is determined by three main drivers: the Inter Tropical Convergence Zone (ITCZ), the *El Nino-Southern Oscillation* (ENSO) and the West African Monsoon. Most parts of the continent have a warm or hot climate, but the humidity and amount of rainfall vary dramatically from area to area (World Book, 2009).

Several studies have reported an increased warming trend in Africa since the 1960s (Nicholson, 2000; Hulme et al., 2001; Thornton et al., 2006; Opiyo et al., 2014). Historical temperature trend for Africa (Figure 2.1) shows warming of approximately 0.7°C over most of the continent during the twentieth century (Thornton et al., 2006). Studies have reported that the mean surface temperature in Africa has increased by 0.5ºC since 1900, and it is anticipated that it could further increase by between 2 to 6ºC by 2100 (Thornton *et al.*, 2006; Amwata, 2013). Although these temperature trends seem to be consistent over the continent, the changes are not always uniform. For example, decadal warming rates of 0.29°C in the African tropical forests (Malhi and Wright, 2004) and 0.1 to 0.3°C in South Africa (Kruger and Shongwe, 2004) have been reported. In South Africa and Ethiopia, studies revealed that the minimum temperature is increasing slightly faster than maximum or mean temperatures (Conway et al., 2004; Kruger and Shongwe, 2004). An increase in the number of warm spells over southern and western Africa was also reported between 1961 and 2000 (New et al., 2006).

Rainfall patterns in Africa are more complicated. There is notable spatial and temporal rainfall variation across Africa (Hulme et al., 2005; Amwata, 2013). There is also a wide variability in rainfall trends over most of Africa. In West Africa (4°-20°N; 20°W-40°E), a gradual decrease in annual rainfall has been observed since the end of the 1960s. Studies reported 20 to 40% rainfall decline between the periods 1931-1960 and 1968-1990 (Nicholson et al., 2000; Chappell and Agnew, 2004; Dai et al., 2004). The tropical rain-forest zone recorded a declines in mean annual precipitation of around 4% in West Africa, 3% in North Congo and 2% in South Congo for the period 1960 to 1998 (Malhi and Wright, 2004). No long term rainfall trend was observed in southern Africa. However, increased inter-annual variability has been observed in southern Africa in the post 1970 period, with higher rainfall anomalies and more intense and widespread droughts reported (Richard et al., 2001; Fauchereau et al., 2003). In some parts of southern Africa (e.g., Angola, Namibia, Mozambique, Malawi, Zambia), a significant increase in heavy rainfall events has also been observed (Usman and Reason, 2004). Changes in seasonality and increased weather extremes have also been observed (Tadross et al., 2005a; New et al., 2006). In recent decades, eastern Africa has been experiencing an intensifying dipole rainfall pattern on the decadal time-scale (Bobadoye et al., 2014). The dipole is characterized by increasing rainfall over the northern areas and declining amounts over the southern areas (Schreck and Semazzi, 2004).

Advances have been made in the understanding of the complex mechanisms responsible for rainfall variability (Reason et al., 2005; Warren et al., 2006; Washington and Preston, 2006; Christensen et al., 2007). Understanding how possible climate regime changes in

El Nino-Southern Oscillation (ENSO) events may affect future climate variability in Africa requires further research. The ENSO events have been reported to have significant influence on rainfall at inter-annual scales in most part of Africa (Giannini et al., 2003; Christensen et al., 2007). In the same region, the intensity and localization of the African Easterly Jet (AEJ) and the Tropical Easterly Jet (TEJ) also has an effect on rainfall variability (Nicholson and Grist, 2003), as well as Sea Surface Temperature (SST) in the Gulf of Guinea (Vizy and Cook, 2001). A relationship has also been observed between the warm Mediterranean Sea and abundant rainfall (Rowell, 2003). The effect of ENSO decadal variations has also been recognized in South-West Africa, influenced in part by the North Atlantic Oscillation (NAO) (Nicholson and Selato, 2000).

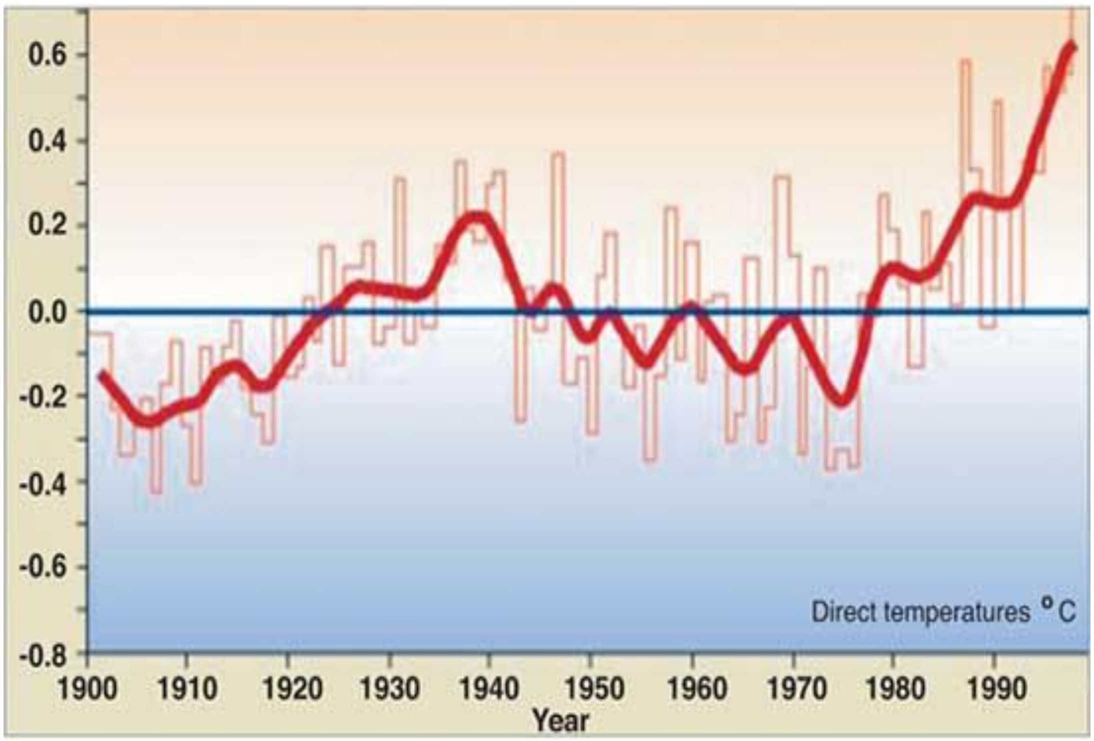

Figure 2.1: Annual mean temperature anomalies in Africa (1900-2000)
Source: IPCC 2014

2.3 Impact of climate variability and change in Africa

Changes in extreme climate related events, such as drought and flood have major impacts in most countries in Africa. Increase in drought occurrence has attracted interest over the past 30 years in most Africa countries (UNEP, 2002). Increase in drought occurrence in recent decades (Figure 2.2) in most African countries impacts on both ecological systems and on society. Droughts have long contributed to tribal conflicts, population dislocation, human migration and the collapse of prehistoric societies (Pandey *et al*., 2003). About 30 percent of the people in Africa lives in drought-prone areas and are vulnerable to the impacts of droughts (World Water Forum, 2000). Tarhule and Lamb (2003) reported that the economic losses from droughts in Africa during the mid 1980s totaled several hundred million U.S. dollars. The impact of drought is felt mainly in the Horn of Africa, the Sahel and southern Africa (Richard et al., 2001; L'Hôte et al., 2002; Trenberth et al., 2007).

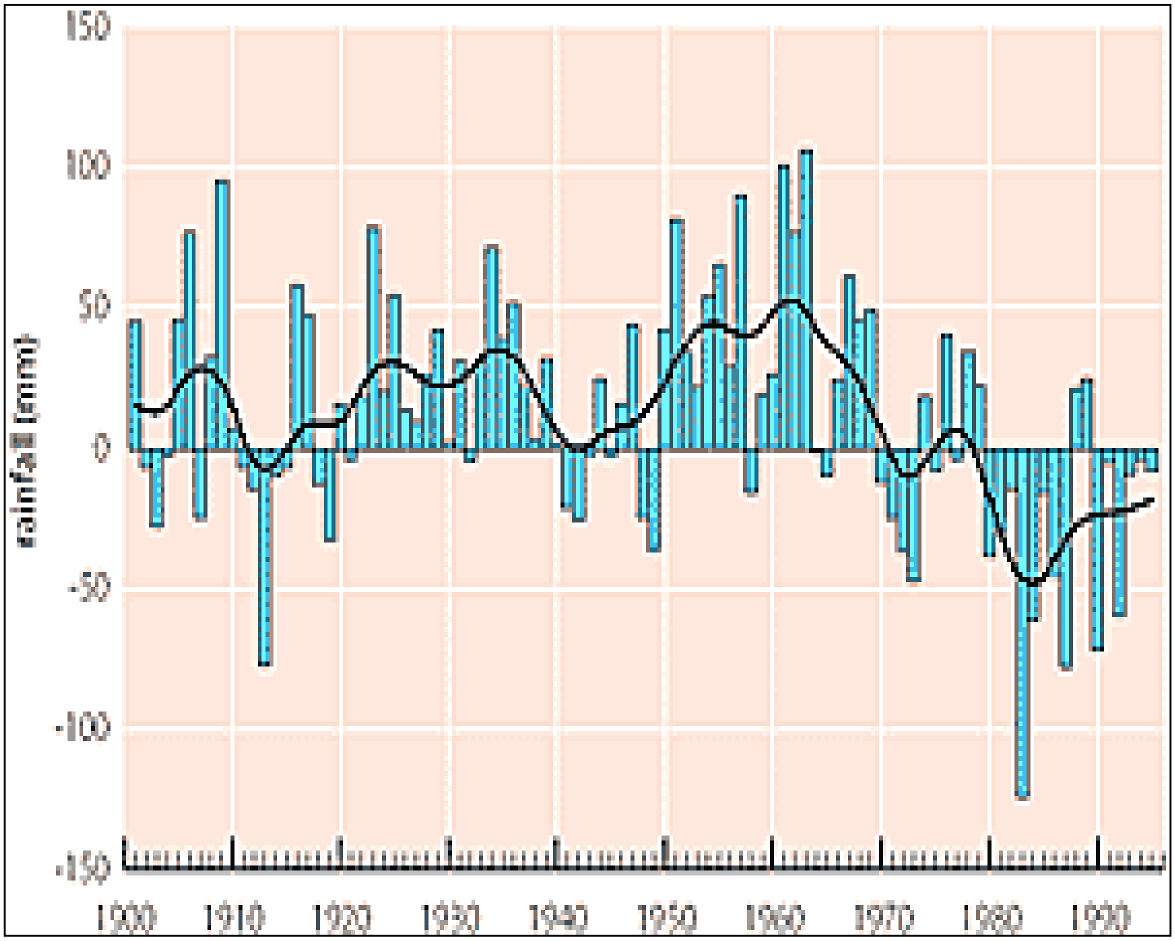

Figure 2.2: Rainfall anomalies in Africa from 1900-2000

Source: FAO 2010

Flood related disasters are also critical and impact on Africa's development. It has severe impacts on livelihoods by destroying agricultural crops, disrupting electricity supply and demolishing infrastructure (UNEP, 2005). Recurrent floods in some countries in east and southern Africa are linked in some cases with ENSO events. Such event causes important economic and human loss results (Mirza, 2003; Obasi, 2005). The *El Niño* floods in Kenya in 1998 resulted in the loss of about 600 lives and 50,000 people were rendered homeless, costing the country about USD 1 billion (SEI, 2009). Even countries located in dry areas (Algeria, Tunisia, Egypt, and Somalia) have not been flood-free (Kabat *et al*., 2002).

The water sector is also sensitive to climate change and variability. Evidence of inter-annual lake level fluctuations and lake level volatility has been observed in some major lakes such as Lake Victoria and Lake Turkana in east Africa since the 1960s. This may probably be as a result of periods of intense droughts followed by increases in rainfall and extreme rainfall events (Riebeek, 2006). About 25% of the contemporary African population experiences severe water stresses (Vörösmarty *et al*., 2005).

The resurgence of malaria and its links to climate change and variability in the highlands of East Africa has recently attracted much research and debate (Hay *et al*., 2002; Pascual *et al*., 2006; Wadinga *et al*., 2010). Influence of climate change and variability on other diseases such as cholera and meningitis are also important areas for research. About 162 million people in Africa live in areas with a risk of meningitis (Molesworth *et al*., 2003). While factors that pre-dispose populations to meningococcal meningitis are not fully understood, dryness, very low humidity and dusty conditions are factors that need to be taken into account.

The agricultural sector which is the main source of livelihood and also a major contributor to national GDP in most African countries is also severely affected by changing climate and variability. This is because most countries in Africa still depend on rain-fed agriculture. In many countries in Africa, farmers and pastoralists have to contend with other extreme natural resource challenges and constraints such as poor soil fertility, pests, crop diseases, and a lack of access to inputs and improved seeds. These challenges are usually aggravated by long periods of droughts and/or floods and are often particularly severe during El Nino events (Mendelsohn *et al*., 2000; Biggs *et al*., 2004; Vogel, 2005; Stige *et al*., 2006).

2.4 Impact of climate variability and change in Kenya

Kenya has various indicators of climate change and variability which include erratic rainfall patterns (Fig 2.3), increase in droughts occurrence, vanishing glaciers on Mt. Kenya, lowering river, lakes and ground water levels (Kanywithia, 2010). These have severe effects on hydro-energy generation, agriculture and food security, forestry, wildlife and tourism, among other climate sensitive sectors (Mutahi *et al.*, 2011). The negative effects of climate variability and change in Kenya include reduced agricultural production, reduced food security, increased incidences of flooding and droughts, widespread disease epidemics, and increased risk of conflict over scarce land and water resources (Amwata, 2013). All these are further complicated by the interaction of multiple stresses, which impact the country's prospects for long-term economic growth and sustainability.

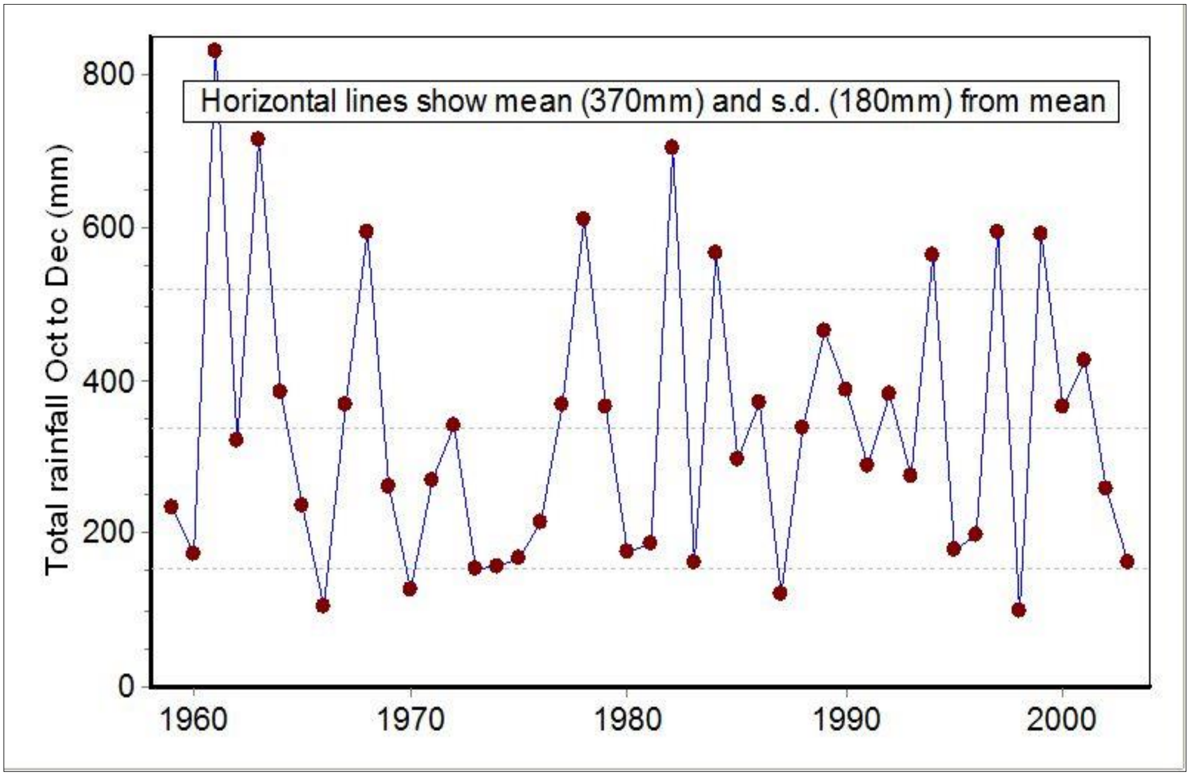

Figure 2.3: Rainfall variability in Kenya from 1958-2003
Source: Cooper *et al*., 2013.

The occurrences of climate extreme events have increased in Kenya in recent decades. Kenya has experience series of droughts and floods which have had devastating socioeconomic and environmental consequences (Serigne and Verchot, 2006). A chronology of the most recent extreme climatic events shows that: In January 1997, the Government of Kenya declared a state of national disaster after a severe drought threatened the livelihoods of about 2 million Kenyans; in 1997/98 the drought was followed by heavy El Niño-induced rains which also destroyed infrastructures and rendered many homeless; the year 2000 witnessed a drought which was the worst in 37 years. In 2002 devastating floods hit many areas of the country leading to human deaths by drowning and landslides, loss of properties and displacement of people. The failure of the long rains in the year 2004 and the subsequent crop failures left more than 2.3 million people in need of assistance (Amwata, 2013). In April 2005 the UN World Food Programme (WFP) estimated that up to 2 million Kenyans, most of them residents of arid or semi-arid regions, needed food assistance due to failed rains (Serigne and Verchot, 2006).

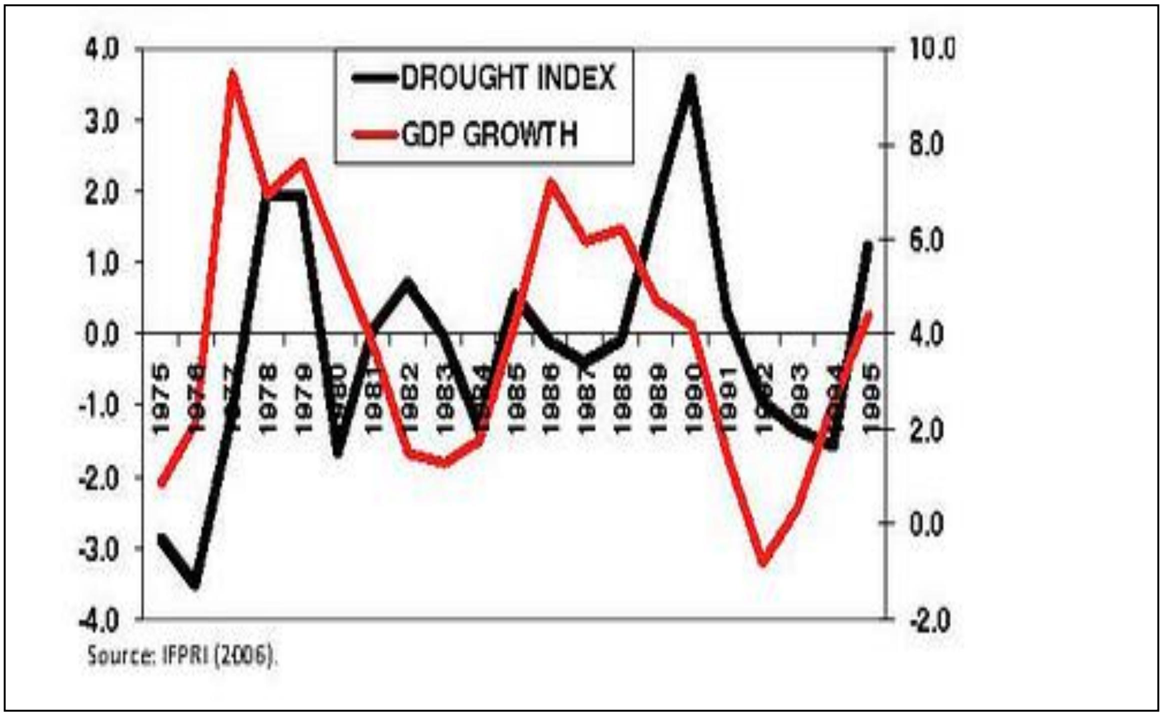

Figure 2.4: Linkage between the palmer Drought Severity Index (PDSI) and GDP growth in Kenya from 1975-1995
Source: IFPRI (2006)

Climate change and variability poses one of the greatest challenges for Kenya to realize its Vision 2030 development blueprint. Figure 2.4 above shows that climate extreme events especially drought are affecting economic growth of Kenya. The continued burden of these extreme climatic events is estimated to cost the economy as much as USD 500 million a year (Amwata, 2013). This is approximately about two per cent of the country's GDP, and is likely to affect long term economic growth (SEI, 2009). For example, the 1999 to 2000 drought cost the Government of Kenya about USD 2.8 billion resulting from the loss of crops and livestock, forest fires, damage to fisheries and reduced hydropower generation and industrial activity. The 2004/2005 and 2009 droughts affected millions of Kenyans and led to rationing of water and energy utilisation. Similarly, the 2006 drought also affected more than 723,000 people in Kenya (SEI, 2009). The *El Niño* of 1997/98 affected about 1.5 million people and was estimated to have a total financial cost of between USD 0.8 to 1.2 billion arising from damage to infrastructure such as roads, buildings and communications, public health effects and loss of crops (Obati, 2005). The annual burden of these events leads to economic costs, approximately over USD 0.5 billion per year (SEI, 2009).

The arid and semi-arid lands (ASALs) of Kenya are most affected by climate change and its extremes (Opiyo, 2014). These areas constitute 80% of Kenya's land mass and support 70% and 25% of the nation's livestock and human populations respectively (Omosa, 2005; Amwata, 2013). These regions receive an annual rainfall of around 500mm and its distribution within the seasons is usually erratic. Pastoralism is the major source of livelihood of those living in the ASALs of Kenya. As climate change looms globally, extreme weather events have already impacted on the livelihoods of pastoralist living in ASALs of Kenya. According to Sergine and Verchot, (2006) pastoral communities living in the predominant arid and semi-arid Counties of Kenya are bearing the brunt of adverse impacts of climate change particularly food insecurity due to droughts, floods and livestock diseases.

Poor infrastructure developments in the ASALs contribute to the increased vulnerability. High population pressure and rapid urbanization is also impacting negatively on the available natural resources in arid and semi-arid regions. The combination of these factors increases Kenya's vulnerability to climate change and its extremes. Therefore, adapting to the expected impacts of climate change and related uncertainties will require holistic planning. Addressing climate change requires both mitigation measures aimed at tackling both the causes of climate extremes such as greenhouse gas (GHG) emissions and adaptation measures to support the country's capacity to cope with the impacts of climate variability and change (UNEP, 2008).

2.5 Vulnerability concept and definition

Vulnerability is a concept that is widely used in different field of specialization. Although vulnerability is an intuitively simple concept, it has different definition based on field of use and even more difficult to quantify and apply in practice (UNEP, 2002; Opiyo, 2014). Vulnerability is described in literature in many and sometimes inconsistent ways. The concept and definitions of vulnerability in literature range from a focus on physical exposure (Deressa 2010), measurement of socio-economic status and access to resources (Timmerman 1981; Amwata 2013), investigation of the ability of different groups to withstand extreme events and recover afterwards (Cutter, 1996).

Gabor and Griffith (1979) defined vulnerability as a threat to which a community is exposed. It takes into account not only the properties of the causal agents involved but also the ecological situation of the community and the general state of emergency preparedness at any point in time. Cutter (1993) defined vulnerability as “the possibility that an individual or group will be exposed to and adversely affected by a hazard”. It is the interaction of the hazards of the place with the social profile of the communities. Vulnerability is also defined by Bohle (2001) as a comprehensive measure of human welfare that integrates environmental, social, economic and political exposure to a range of harmful disturbances. Different organizations have also defined vulnerability in different ways based on their role and their field of interest. The Vulnerability Analysis and Mapping (VAM) project of WFP (1999) refers to vulnerability in terms of food security. It defined vulnerability as the probability of an acute decline in availability of food or consumption levels below minimum survival needs. It is a function of exposure to risk factors, such as drought, conflict, or extreme price fluctuations and underlying socio-economic processes which reduce the ability of people to cope.

The United Nations (1993) in defining vulnerability distinguished two important considerations in the concept of vulnerability. First, they distinguished between economic vulnerability and ecological fragility, explaining that economic vulnerability finds its root partly in ecological factors (for example, cyclones). Thus vulnerability indices “should reflect relative economic and ecological susceptibility to external shocks”. Secondly, they differentiated “between structural vulnerability, which results from factors that are durably independent from the political will of countries, and the vulnerability arising from economic policy, which is a result of choices made in a recent past”. Finally the intergovernmental panel for climate change (IPCC, 2014) defined vulnerability as “the degree to which a system (natural or social) is susceptible or unable to cope with the adverse effect of climate change and its extremes”. It expressed vulnerability as a function of adaptive capacity (ability of the system to cope with or adjust to the changing context); sensitivity (ability of a system to be affected); and exposure (the incidence of events). Vulnerability can therefore be seen as made up of three elements: exposure to hazard, sensitivity and adaptive capacity. People having more capability to adapt to extreme events are naturally also less vulnerable to risk.

2.6 Approach to vulnerability assessment

Assessing vulnerability at the global, regional, national and local level is important for current and future planning and decision making. It is useful for establishing who is vulnerable, where they are and what strategies are needed to combat vulnerability. It helps decision-makers in government, donor agencies and non-governmental organizations (NGOs) to take evidence based decisions. Generally, three main conceptual approaches are used in analyzing vulnerability to climate change: the biophysical approach (impact assessment); socio economic approach; and integrated approach.

2.6.1 Biophysical approach

The biophysical approach to analyzing vulnerability which is also called impact assessment attempts to assess the level of damage caused by a given climatic extreme on both social and biological systems. For example, the yield impact of climate change can be analyzed by modeling the relationship between climate variables and crop yield (Olsen *et al*., 2000); also the impact of climatic variables on pastoralism can be measured by relating climate extremes to livestock production (Ombogo, 2013). Several other impact assessments on human health (Martens *et al*., 1999; Wandiga *et al*., 2010); and ecosystem damage (Forner, 2006) have been conducted using the biophysical approach. The emphasis of the biophysical approach is on the vulnerability to biophysical conditions (Liverman 1990). This is the main approach used in studies of impact of natural hazards and climate variability and change (Hewitt 1997). Füssel, (2007) identified this approach as a risk-hazard approach; he described it as an end-point analysis that responds to research questions such as ‘to what extent is climate change and its extreme affecting human and social system’. The biophysical approach has its limitations. Assessment of biophysical factor does not provide a sufficient understanding of the complex dynamics of vulnerability to climate change and variability. It focuses on impact of climate extremes on a system not giving consideration to other factors. This approach is difficult to apply to people whose exposure to hazards largely depends on their behaviour, as determined by socioeconomic factors. It neglects both structural factors and human agency in understanding vulnerability and adapting to it. The approach overemphasizes extreme events while ignoring the root causes and everyday social processes that influence vulnerability (Liverman 1990; Hewitt 1997). For example, the biophysical approach can only measure the effect of drought on crop yield, but it will not reflect how various household or communities are influenced or affected by the change in crop yield.

2.6.2 Socio-economic approach

The socio-economic vulnerability assessment approach focuses vulnerability analyses on people. It concentrates on socio-economic and political status of individuals or social groups (Fussel, 2007; Deressa, 2010; Opiyo, 2014). Individuals in a community vary in terms of level of education, wealth, health status, access to credit, access to information and technology, formal and informal (social) capital and political power, which are responsible for variations in vulnerability levels (Füssel, 2007; Deressa *et al.*,2008). Consequently, vulnerability is considered to be a state that exists inside a system before it encounters a hazard event (Kelly and Adger 2000). In this contest, vulnerability is measured as a function of institutional and economic changes in the society. The socio-economic approach focuses on the state of individuals, groups or communities in terms of their ability to cope or adapt to external stress placed on their livelihoods. It considers the availability of resources by individuals or communities and their ability to call on these resources when needed. The term ‘response capacity’ and ‘coping capacity’ are used to denote the concept.

The main limitation of the socio-economic approach is that it focuses only on variation among individuals or social group. In reality, societies vary not only due to socio-political factors but also because of environmental or biophysical factors. This method overlooks the intensities, frequency and probabilities of environmental hazards such as drought and floods. The socio-economic approach does not account for the impact of natural events which can have significant impact on vulnerability of individuals or communities. For example, increase in frequency of forest fire can increase the vulnerability of a community when compared to another community with similar socio-economic characteristics.

2.6.3 The integrated approach

The integrated approach to climate vulnerability assessment combines both the socio-economic and bio-physical factors to measure vulnerability to climate change and its extremes. Researchers realizing the limitations in the bio-physical and socio-economic approach to vulnerability assessment developed the integrated approach to combine both internal factors of a vulnerable system and its exposure to external hazard to determine vulnerability (Cutter, 1993; Fussel, 2007; Deressa 2010; Opiyo, 2014). The hazard-of-place model (Cutter *et al*., 2000) and the coupled vulnerability framework (Tunner II *et al*., 2003) are examples of the integrated vulnerability approach.

This approach agrees with Cutter (1996) definition of vulnerability as ‘‘the likelihood that an individual or group will be exposed to and adversely affected by a hazard. It is the combination of the hazards of place with the social-economic profile of communities.’’ In the context of food insecurity, the World Food Programme (2004) defines vulnerability as being composed of two principal components, namely: (i) risk of exposure to different types of shocks or disaster event (ii) ability of the population to cope with different types of shock or disaster event. Integrated definitions of vulnerability are also commonly used in environmental change and climate change vulnerability assessment with reference to regions, communities, or other social units (Deressa 2010; Opiyo, 2014). IPCC (2014) definition of vulnerability as a function of adaptive capacity, sensitivity and exposure accommodates the integrated approach to vulnerability studies

(Fussel and Klein, 2006; Deressa, 2010). Sensitivity and exposure in the IPCC terms relates to biophysical approach while adaptive capacity talks about the socio-economic properties of a household or a community.

The integrated approach to vulnerability assessment is not without its own limitations. Finding a common and acceptable method of combining and analyzing bio-physical and socio-economic indicators is the main challenge of this approach. Allocating weights to different parameters with different units ranging from socio-economic parameters such as income levels, educational qualifications, to bio-physical parameters such as drought frequency and flood occurrence is also a challenge in the integrated approach.

2.7 Adaptation and coping strategies of pastoralist communities to climate change and variability

Adaptation to climate change is a broad concept that covers actions taken by individuals, communities, private companies and public bodies such as governments to enhance resilience to climate change and variability (Mitchell and Tanner, 2006). IPCC (2014) defined adaptation to climate change as "adjustment in ecological, social or economic system in response to actual or expected climatic stimuli and their effects to moderate or offset potential damage or take advantage of opportunities associated with change in climate". Successful adaptation strategies should reduce vulnerability. It builds on and strengthens existing coping mechanisms, targeting climate change vulnerability with specific measures and integrating vulnerability reduction into wider policies (Mitchell and Tanner, 2006). The aim of an adaptation strategy should be to increase the capacity of a system to survive external weather shocks or changes. For many decades, pastoral communities in ASALs have developed indigenous ways of adapting to varying degree of extreme weather events; however, recent increase in the frequency of occurrence of these weather events are stretching the resilience of pastoral communities.

Pastoral communities employ a number of strategies to adapt to the impact of climate change and its extremes. The main concern during a drought year is for each household to secure its survival and the survival of its herds (Keya, 2001). Some adaptations measures can be clearly identified as being triggered by climate variability and change, and those adaptations are often purposeful and directed. Others can also arise as a result of other non-climate-related social or economic changes. Some of the adaptation and coping strategies used by pastoralist in ASALs of Kenya include mobility, large and diverse herds, herd separation and splitting, informal social security systems, and engaging in other livelihood activities like crop farming, charcoal burning, and wage labour. Unfortunately, some of these strategies that have served the pastoralist communities very well in the past are presently constrained due to increase in thefrequent occurrence of droughts and rapid social and economic changes.

Livestock mobility is an inherent strategy of pastoralists to optimize production of a heterogeneous landscape under unstable climate (Ndikumama *et al*., 2000). Pastoralist mobility has two dimensions. The first is resource utilization mobility, where pastoralists continue to move in response to unpredictable forage and water availability. The strategy allows pastoral herds to maximize dispersed forage resources when they are available and most nutritious. Pastoralists also move their herds to escape drought occurrence in a particular location. The distances moved depend on availability of limited resources and the social and political "environment" shared with neighbours (Kagunyu, 2014). Mobility is an intrinsic part of the pastoralist existence and needs to be understood as the strategic mobility of people and livestock. The social networks amongst pastoralist offer security and insurance that allows for flexibility in mobility of livestock and people (Opiyo, 2014). Mobility is therefore a fundamental adaptation strategy to changing climatic condition and trends in the ASALs of Kenya. Studies have also shown that ASALs ecosystems are healthier where mobile pastoralism continues to be practiced effectively (Niamir-Fuller 2000; Nassef *et al.* 2009; Agrawal 2010; Opiyo 2014). Grazing opens up pastures, stimulates effective vegetation growth, fertilizes the soil with animal dung and enhances its water infiltration capacity as hoof action breaks up the soil crust. It also aids in seed dispersal to maintain pasture diversity, prevents bush encroachment and enhances the cycling of nutrients through the ecosystem (Goldman and Fernando, 2013).

Herd diversification is another coping strategy used by pastoral communities in ASALs of Kenya. This involves keeping several species/types of livestock. The rearing of different livestock species has ecological and economic advantage for the pastoralist (Kinyamario and Ekaya, 2001). Diversification optimizes the use of heterogeneous ecosystem and meets different socio-economic obligations. Livestock species have different uses, feeding preferences, levels of physiological and behavioural adaptation to extreme climatic events. Therefore, livestock diversification is necessary for exploitation of the different ecological niches and the animal's complementary adaptabilities, as well as for meeting social and economic needs during drought conditions.

Livelihood diversification is also a common adaptation strategy to climate change and variability in ASALs of Kenya. Diversification of sources of income is a core livelihood strategy of rural livelihoods systems in most developing countries (Little *et al.* 2001; McCabe *et al.* 2010). Pastoralists diversify their sources of income during extreme climatic condition such as drought (Opiyo, 2014). Alternative sources of livelihood engaged by pastoralist include livestock trading, selling of hide and skins, and cultivating crops. Pastoralist are also involved in a variety of wage earning occupations ranging from professional to manual labour; and entrepreneurial activities including shop keeping, craft production and sales, and transportation. Pastoral communities also occasionally use wild fruits and vegetables such as *khona* (*Hyphene coriaceae*), *domog* (*Grewia tenax*), *bejelo* (*Lannea alata*), and *madeer* (*Cordia sinensis*) as food during times of natural calamities. Some of these fruits and vegetables are readily available during the drought period while others have to be collected before a drought and preserved for use later (Kagunyu, 2014).

2.8 Transdisciplinary research approach

The traditional disciplinary approach to research has proved incapable of addressing complex interdependent issues which are not reserved to particular sectors or disciplines (Klein, 2008). New and emerging challenges such as climate change with non-linear dynamics, uncertainties, and high political stakes in decision-making requires the integration of various sources of knowledge to successfully address them. The increase in complex societal challenges is steering the interest of researchers to re-think their approach, strategies and concepts for addressing these emerging challenges.

Originally formulated as an alternative to the stereotyped methodology of traditional scientific inquiry, transdisciplinary research is considered a viable mode for the production of knowledge in design. It has a strong orientation of addressing complex societal challenges using multiple sources of knowledge (Balsiger, 2004). Transdisciplinary science has been defined as the "collaboration among scholars from two or more disciplines in which the collaborative products reflect an integration of conceptual and/or methodological perspectives drawn from two or more fields" (Stokols *et al*. 2003). The major difference between transdisciplinary and other forms of research (Figure 2.4) is that it aims at solving real world problems (Lawrence and Despres, 2004; Swart *et al*., 2014). Transdisciplinarity gains importance as a problem-solving approach. It starts from the concrete need of addressing a problem, analysing it and trying to tackle it using different approaches (Klien, 2008).

Transdisciplinary research approach is needed when knowledge about the problem is vague, when the concrete nature of problems is disputed, and when there is a great deal at stake for those concerned by problems and involved in dealing with them (Pohl and Hirsch Hadorn 2008). The advantages of transdisciplinary research approach over disciplinary, multidisciplinary, and interdisciplinary research approaches includes; (1) It supports the analysis of complex problems from different perspectives and gives a detailed understanding of the issues at hand (2) It enables researchers to deal with complexity, uncertainty, change and imperfection (3) It encourages system thinking and guides the participants to look at the challenges holistically (4) It involves researchers and the public in the whole research process. Consequently, it enables the integration of different forms of knowledge overcoming the epistemological barriers between academia and non-academia (5) Transdisciplinary approach enables participants to jointly learn about (and understand) complex problems and to facilitate knowledge exchange (6) It bridges the gap between research and practice by targeting societal issues or needs and expectations.

The overall goal of transdisciplinary research is to provide a link between research knowledge and decision-making processes (Lawrence and Despres, 2004). It seeks feasible, socially acceptable, effective and sustainable solutions to societal problems (Balsiger, 2004). A transdisciplinary approach would also incorporate experiences and knowledge from non-academics and allow these groups to be equal participants in the research process. It involves collaboration, participation and working together of all stakeholders, both academic and non-academic, researchers and end users towards solving a peculiar challenge. A transdisciplinary research approach acknowledges that academics do not have a monopoly on wisdom (Albrecht *et al*., 1998), and seeks to understand the present world by unifying knowledge from both academic and non academic perspectives (Ramadier, 2004).

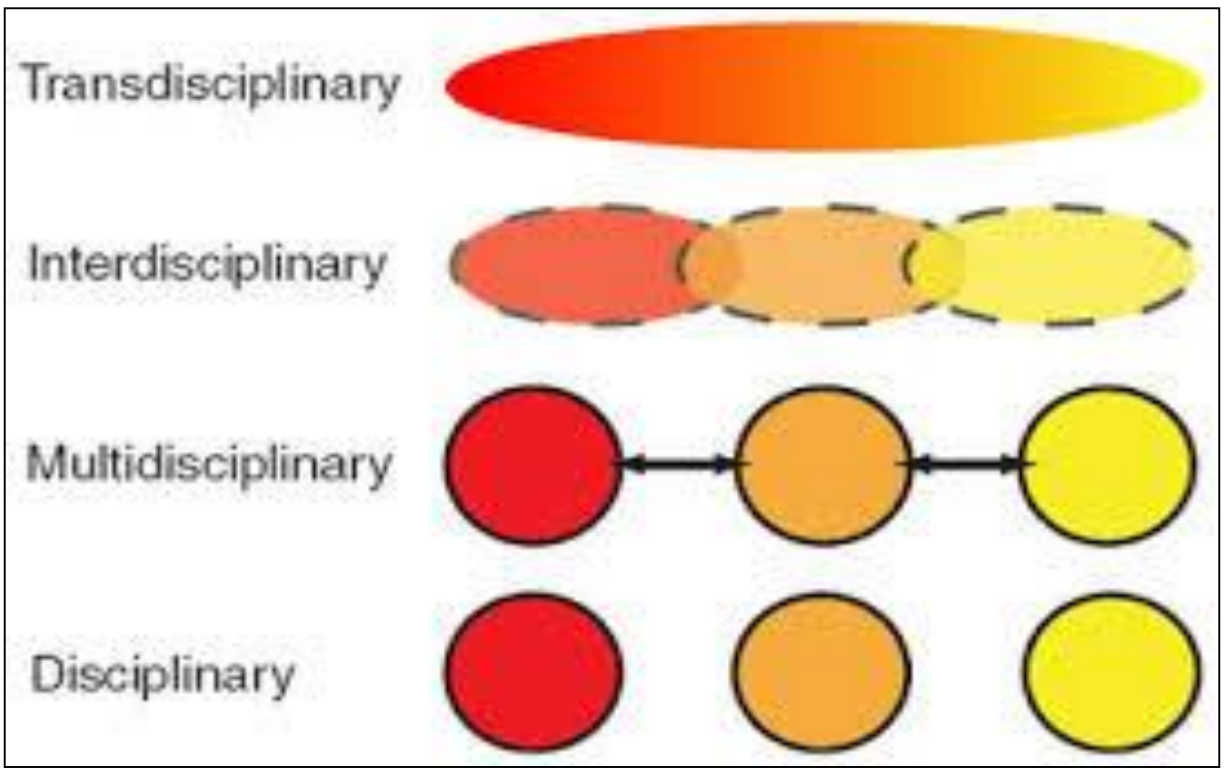

Figure 2.5: Difference between transdisciplinary and other approach to research
Source: ERA Steering (2011).

The key tenets of transdisciplinary research approach should involve the following:

(1) Transdisciplinary research requires the use of a common conceptual framework among members of a research team to address particular research questions (Giacomini, 2004). In this way ‘trans’ refers to the use of research concepts, methods and questions that transcends the traditional disciplinary borders (Rosenfield, 1992; Lawrence and Despres, 2004). This distinguishes transdisciplinary research from other research approaches such as disciplinary (where members of a research team are from the same discipline), multidisciplinary (where research members come from different disciplines but work independently) and interdisciplinary (where researchers from different disciplines work together but stay within their disciplinary boundaries). The end result of transdisciplinary research should be a multiplicity of perspectives contributing to a shared understanding that is both broader and deeper than one likely to come from within a single discipline (Albrecht *et al*., 1998; Gibbons *et al*., 1994).

Rosenfield (1992) describes transdisciplinary as a process where researchers become sufficiently familiar with concepts and approaches of other disciplines among the research team, resulting in the fading of both disciplinary boundaries and disciplinary hierarchies.

(2) A transdisciplinary research approach consists of collaborations not only between researchers from different academic fields but also between researchers and non-academic groups with a stake in the problems under investigation (Balsiger, 2004). A transdisciplinary research approach should incorporate both scientific and non-scientific knowledge (Balsiger, 2004).

(3) Transdisciplinary research is an action-oriented approach to research (Lawrence and Despres, 2004). This means that the research questions to be addressed emerge through consultation and interaction among the research team (both academic and non-academic). The research questions should be socially useful, feasible and should lead to effective and sustainable solutions (Balsiger, 2004).

(4) A transdisciplinary research approach does not end with production of knowledge. Rather, there is a constant flow between knowledge and practical application. The process should be reflexive, with the possibility of groups dissolving and other groups emerging throughout the research process (Gibbons *et al*., 1994).

2.9 Importance of Transdisciplinarity in climate change research

The multiple challenges posed by climate change and variability demands that human settlements adapt to uncertain and unavoidable impacts. The complex nature of climate change requires collaborative effort by different stakeholders to facilitate an integrated and coordinated response to its impacts. Raymond *et al*., (2010), argued that the prevailing system of scientific knowledge production is not able to address complex environmental challenges such as climate change. Transdisciplinary research approaches have been known for being well placed to help responses to complex multidimensional problems such as climate change. Transdisciplinary approach to research is usually useful when a socially relevant problem is characterised by uncertainty and complexity. It is used when the concrete nature of problems is in dispute (Scholz and Tietje, 2002), and when there is a lot at stake for those concerned with these problems (Pohl and Hirsch Hadorn, 2007).

The various challenges human settlements are facing as a result of changing climate and numerous efforts to adapt transcend disciplinary boundaries that underpin the structure and functioning of many research enterprises.They are entangled with socio-political context as well as biophysical variables, and require the participation of multiple stakeholders to produce socially acceptable outcomes (Carew and Wickson, 2010). Climate change adaptation research has transformed from a purely mono-disciplinary scientific concept to a highly relevant socio-political and economic challenge with a high degree of complexity (Solomon *et al*., 2007). Climate change adaptation challenges researchers to work in ways that breach traditional disciplinary boundaries to include perspectives from different stakeholders, multiple methodological approach and concepts from different disciplines (Carew and Wickson, 2010; Deppisch and Hasibovic, 2013). Studies have shown that lay people have specific knowledge and experience and are sensitive to socio-political issues which often are not acknowledged by experts' models (Fiorino, 1990; Mauser *et al*., 2013). The inherent complexity and hybrid nature of climate change adaptation research has led researchers to advocate for transdisciplinary approaches to adaptation-related research and policy development (Deppisch and Hasibovic, 2013; Mauser *et al*., 2013; Parry *et al*., 2014). Specifically, it is argued that transdisciplinary approaches are critical for research that requires ‘collective leadership, complex collaborations, and significant exchanges among scientists, decision makers and knowledge users’ (Gosselin *et al*., 2010).

The characteristics of transdisciplinary approach to research makes it useful for research geared towards policy development using collective processes and involving many ‘policy cultures’ (Pohl and Hirsh Hardon, 2007) as is the case for most climate change adaptation research. There are two critical aspects related to climate change adaptation that can certainly be enhanced through transdisciplinary research approaches: (1) collaboration and co-production of useful climate change knowledge; (2) bridging the science–policy interface whereby scientists and practitioners work together to generate new and/or useful knowledge. The complex and dynamic nature of climate change requires that all stakeholders (government, NGO, scientist and communities) work collaboratively to enable effective adaptation. Effective transdisciplinary research approaches can create opportunities for such collaborations to occur or at least to establish a dialogue between participants (Wickson *et al*., 2006).

CHAPTER THREE

STUDY AREA

3.1 Introduction

This chapter gives a detailed description of the study area in the southern rangeland of Kenya. The southern rangelands comprise Kajiado, Makueni, Mwingi, Kitui and Machakos Counties. This study was conducted in Kajiado County. The County was selected because of high population of Maasai pastoralists in the county, and also because of easy accessibility by the researcher. The field study was carried out in Kajiado east sub-county. The sub-county consists of five administrative wards. This chapter also provides an overview of locations, biophysical factors, population dynamics and climate related events in the study area.

3.2 Study area

3.2.1 Location and Description

The study was carried out in selected villages in Kajiado County in Kenya. Kajiado County is located in the southern tip of the former Rift valley province between longitudes 36^{o}5 and 37^{o}5 and latitudes 1^{0}0 and 3^{0}0 South (Amwata, 2013). It covers an area of 19,600Km^{2} (CBS, 1981). Kajiado County is bordered by Tanzania to the south, Taita Taveta County to the east, Narok County to the west and Nakuru, Kiambu, Nairobi and Makueni Counties to the north. The county is divided into five administrative sub counties: Kajiado West, Kajiado North, Kajiado South, Kajiado East and Kajiado Central. It is also divided into four eco-zones: the Rift valley, the upland Athi Kapiti Plains, the Central Hills and Amboseli Plains (Amwata, 2013). Field study was conducted with communities in Kajiado East sub-County. The sub-County has five administrative wards (Oloosirkon/Sholinke, Kitengela, Kapetui North, Kenyawa-Poka and Ilmaroro). Kajiado East has a land size of 2,610.30sq.km and the major towns include: Kitengela, Isinya, Emali and Imaroro.

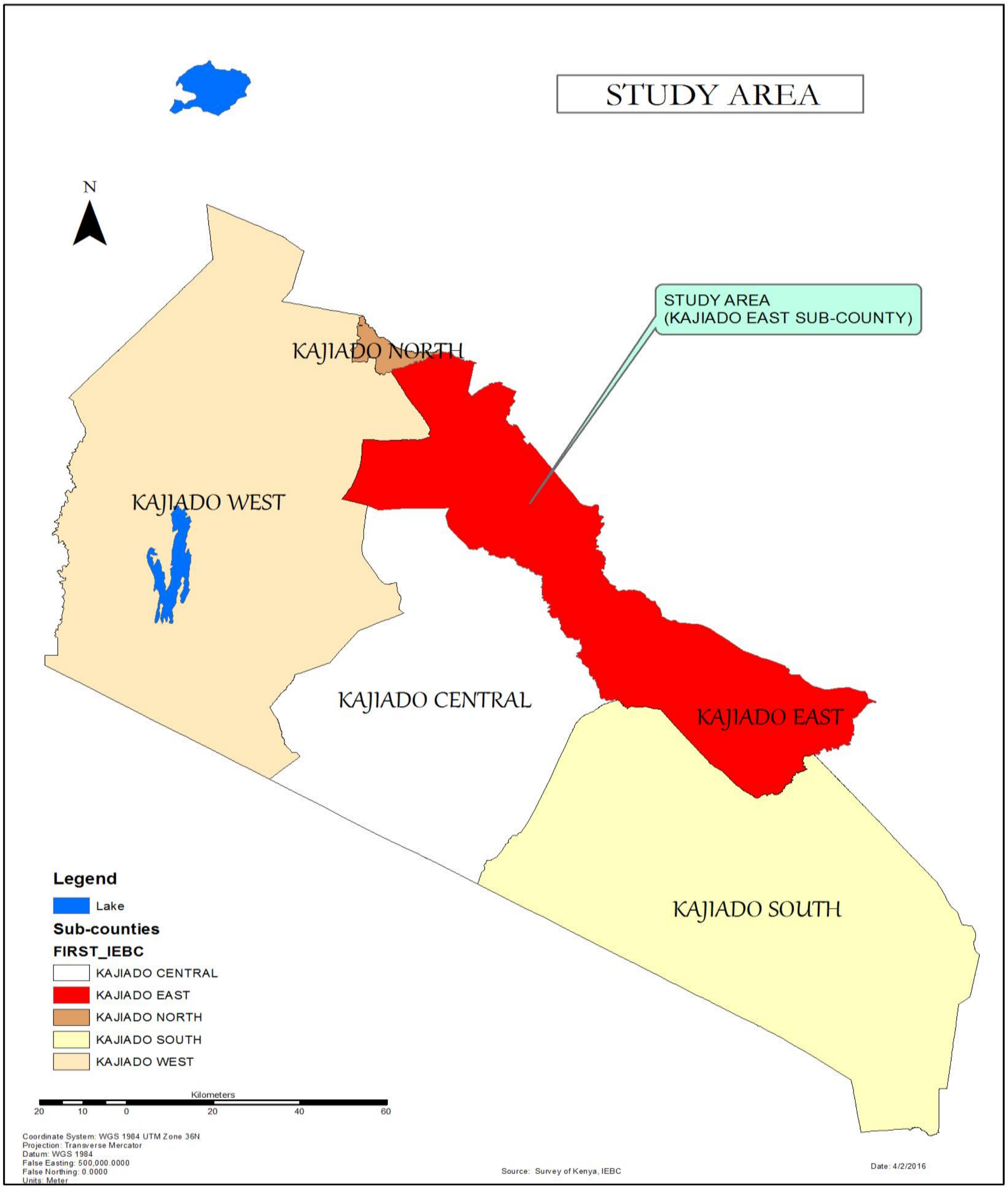

Figure 3.1: Map of Kajiado County

3.3 Demographic features

Kajiado County is inhabited by a high population of Maasai pastoralist and agro pastoralist who have been practicing transhumance as their traditional mode of life under communal land ownership. However the lifestyle has undergone transitional change due to land reform which has seen the emergence of individual and private land ownership. The 2009 population census (Table 3.1) revealed that Kajiado County has a population of 687,312 people. In 1999 and 1989 the population of the County was 406,054 and 258,659 respectively (CBS, 2009). This shows that Kajiado County has an annual growth rate of 4.5 percent, a rate that is higher than the national annual growth rate of 2.9 percent. The population density in Kajiado County has also increased over the years from 1, 3, 4, 7, 12, 17 and 31 persons per Km^2 in 1948, 1962, 1969, 1979, 1989, 1999 and 2009 respectively (ROK, 2009). Kajiado East has a population of 137,496 people. Oloosirkon/Sholinke ward has the highest population of 34,175 people, followed by Kitengela with 30 663 people, Kapetiei North has 29,989 people, Kenyawa-Poka ward has 24,559 people and Imaroro ward has 17,096 people (GOK, 2013).

Table 3.1: Kajiado County administrative constituencies and their population

	Constituency	Population(2009 Census)	No. of wards
1	Kajiado North	202,651	5
2	Kajiado Central	102,978	5
3	Kajiado East	137,254	5
4	Kajiado West	106,933	5
5	Kajiado South	137,496	5
	Total	**687,312**	**25**

Source: GOK, 2013

Table 3.2: Kajiado East sub-County administrative wards and their population

Name	Population (2009 National Census)	Area (Sq. Km)	Description	No of people /sq.km
Kaputiei North	29,989	88.70	Isinya, Enkigiriri, Ilpolosat and Olturoto Sub–Locations of Kajiado County	338
Kitengela	30,663	102.90	Olooloitikoshi location of Kajiado County	298
Oloosirkon/ Sholinke	34,175	287.40	Kitengela Centre, Oloosirkon and Sholinke Sub–Locations of Kajiado County	119
Kenyawa-Poka	24,559	1,340.40	Sultan Hamud, Nkama, Imbilin, Emali, Kiboko, Merrueshi, Masimba and Imbuko Sub–Locations of Kajiado County	18
Imaroro	17,096	790.90	Ilmunkush (Emarti, Erankau), Arroi and Imaroro (Kiloh, Lensonkoyo Sub–Locations of Kajiado County	22

Source: GOK, 2013

Table 3.3: Population of Kajiado County by age cohort

Age cohort	2009 projection			2012 Projections			2015 Projections			2017 Projections		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
0-4	56172	54591	110763	65959	64103	130062	73415	71348	144763	81712	79412	161124
5-9	48440	47402	95842	56880	55661	112541	63309	61953	125262	70465	68955	139420
10-14	40160	39366	79526	47158	46225	93383	52488	51450	103938	58420	57265	115685
15-19	32318	34114	66432	37949	40058	78007	42238	44586	86824	47012	49625	96637
20-24	33929	43374	77303	39841	50932	90773	44344	56688	101032	49356	63095	112451
25-29	35722	36250	71972	41946	42566	84512	46687	47377	94064	51964	52732	104696
30-34	26909	24084	50993	31598	28280	59878	35169	31477	66646	39144	35034	74178
35-39	21693	18752	40445	25473	22019	47492	28352	24508	52860	31556	27278	58834
40-44	15178	12571	27749	17823	14761	32584	19837	16430	36267	22079	18287	40366
45-49	10912	9402	20314	12813	11040	23853	14262	12288	26550	15873	13677	29550
50-54	7460	6382	13842	8760	7494	16254	9750	8341	18091	10852	9284	20136
55-59	5161	4079	9240	6060	4790	10850	6745	5331	12076	7508	5934	13442
60-64	3716	3508	7224	4363	4119	8482	4857	4585	9442	5406	5103	10509
65-69	2305	2255	4560	2707	2648	5355	3013	2947	5960	3353	3280	6633
70-74	1885	2003	3888	2213	2352	4565	2464	2618	5082	2742	2914	5656
75-79	1083	1159	2242	1272	1361	2633	1415	1515	2930	1575	1686	3261
80+	1939	2718	4657	2277	3192	5469	2534	3552	6086	2821	3954	6775
N/S	164	156	320	193	183	376	214	204	418	239	227	466
Total	345146	342166	687312	405285	401785	807070	451092	447197	898289	502077	497742	999819

Source: GOK, 2013

3.4 Biophysical features

Kajiado County varies in altitude from about 500m above sea level (a.s.l.) around Lake Magadi to about 2500 a.s.l. in the Ngong Hills. The three main topographic features in the county are: Rift valley, Athi Kapiti and Central Broken Ground (CBS, 1981). There is a low depression in the Rift valley on the western side of the county running from North to South. The Rift valley is made up of steep faults giving rise to a plateau, structural plain and scarps. The plateau has features such as Lake Magadi and Lake Natron and both Lakes have substantial deposit of Soda-ash. The Athi Kapiti plains are made up of mainly of gently undulating slopes which become rolling and hilly towards Ngong Hills and it has an altitude of 1,580 - 2,460 a.s.l. The Hills are the catchment area for Athi River. The Central Broken Ground encompasses 20 to 70km wide, it stretch from North Eastern boarder across the county to the Southwest. It has an altitude ranging from 1,220 to 2073m a.s.l. There are also dry river beds which are sources of sand for the building and construction industry in the area (ROK, 2009). The Major rivers in Kajiado County are Athi, Ewaso Ngiro and Pakase.

The County has three geological regions: quaternary volcanic, Pleistocene and basement rock soils. Alluvia soils can also be found in some areas. Quaternary Volcanic soil is found in the Rift Valley. Basement System Rocks which comprise various gneisses, cists, quartzite and crystalline limestone, are found mainly along the river valleys and some parts of the plains. Pleistocene soils are found in the inland drainage lake system around Lake Amboseli. Quarrying of building materials is also done within the County.

Kajiado County also boasts of a wide range diverse fauna and flora. The animals found in the county include Wilde Beasts, Gazelles, Zebras, Hyenas, Giraffes, Warthogs, Elephants, Lions, Leopards and Elands, and diverse bird species. Areas designed for game reserves are; Amboseli National Park which covers a total of 392Km^2 and Chyulu conservation area which is 445Km^2.

3.5 Climate Information

Kajiado County has a bimodal rainfall pattern that is influenced by altitude. It has a mean annual rainfall of between 300–800mm. However, areas with high altitudes like Ngong and Loitokitok experience heavy rainfall that can be as much as 1200mm of rains per annum. Kajiado County has two main rainy seasons: the long rainy season from March to May and the short rainy season from October to November. Analysis of rainfall for the two rainy seasons reveals that most areas receive 50 percent of annual rainfall during the March to May period and 30 percent during the October to December period (ROK, 2009). Temperatures in Kajiado County vary with altitude and season. The highest temperatures of about 34^0C are recorded around Lake Magadi while the lowest of 10^0C is experienced at Loitokitok on the eastern slopes of Mt. Kilimanjaro (ROK, 2009). The coolest months of the year are between July and August, while the hottest months are from November to April. Livestock system mainly pastoralism, agropastoralism, cropping and mixed crop dominate the main sources of livelihood in Kajiado County. In the high rainfall areas of Loitokitok, farmers grow millet, sorghum, groundnut, maize, pigeon peas and cowpeas.

Most of the Kajiado County lies between arid and semi-arid zones. Most part of the County falls within agro-climatic Zone V (55%) and VI (37%), which are semi-arid and arid respectively (Table 3.4). Agroecological zone V receives 450 to 800mm of annual rainfall and has a moisture index of 25 to 40%. Pastoralism and agropastoralism are the main sources of livelihood of people living in agroecological zones V and VI. The rest of the district falls in agro-climatic Zone II, III and IV, accounting for a sum of only 8% of the County. The County has a total of 92% of ASAL ecosystems with only Athi-Kapiti ecozone free of arid patches. Rift Valley ecozones lead in percentage of semi-arid lands (71%) while vast areas of Amboseli ecozones are arid (69%).

Table 3.4: Climatic zones in Kenya rangelands

Agro-ecological zones	Climate	Moisture index (%)	Annual Rainfall (mm)	% of Kenya lands area
IV	Semi-humid to semi-arid	40-50	600-1100	5
V	Semi-arid	25-40	450-800	15
VI	Arid	15-25	300-550	22
VII	Very arid	<15	150-350	46

Source: Bekure *et al*, 1991

Table 3.5: Distribution of agro-climatic zones in the four ecozone of Kajiado County

Ecozone	% of ecozone land area in zones			
	IV	V	VI	Total area (km^2)
Rift valley	7	71	23	6850
Athi-Kapiti	31	69	27	2040
Central Hills	14	69	27	4400
Amboseli	15	26	69	6270
Kajiado District	8	56	36	19560

Source: Bekure *et al.*, 1991.

CHAPTER FOUR

METHODOLOGY

4.1 Introduction

The methods that were used to obtain both primary and secondary data needed to achieve the study objectives are described in this chapter. Primary data was acquired mainly from household interviews, key informant interviews and Focus Group Discussions. Primary data collected had information on vulnerability and adaptation strategies directly from the Maasai pastoralist and other stakeholders. In addition, secondary data on annual rainfall and annual temperature in the study area from 1970-2013 was also collected from Kenya Meteorological Service (KMS) to analyze rainfall and temperature trend in the study area. Data was also obtained from existing literature including unpublished and published research reports from relevant ministry departments, peer-reviewed journals and online resources.

4.2 Data collection Process

4.2.1 Reconnaissance survey

Initial reconnaissance survey of the area was carried out prior to the commencement of the field study. This was done to meet the relevant stakeholders especially the communities and introduce the study objectives. The researcher also met with others stakeholders such as local administrators, National Drought Management Authority (NDMA) officials, Kajiado County meteorological and veterinary directors, and also relevant NGOs staffs in the county. The pre-study session was very useful as it helped to familiarize the researcher with the local communities to gain their trust, understand their perspective about climate change and integrate members of the community into the research process.

4.2.2 Training of local field assistants and Questionnaire pre-testing

A total of four (4) field assistants were recruited locally among the Maasai pastoralist in the study area. This was done to enhance participation of the communities who are co-producer of knowledge in the research process. The training process was conducted for two days and piloted before the beginning of the interviews. The objective of the training was to minimize bias and errors in data collection and to familiarize the field assistants with the objectives of the research.

A pilot test run of research tools was conducted around Imaroro community before the commencement of the field work. This was done to check the suitability of the research tools and also access the ability of the research assistant to administer research the tools. The questionnaire was finalized taking into consideration the necessary corrections and modifications from the pilot surveys, after which the actual study was conducted.

4.2.3 Climate data collection

Rainfall data from four different stations in Kajiado County were obtained from the Kenya Meteorological service (KMS) and used for this analysis. Average monthly rainfall were collected from Ngong forest station in Kajiado north area located at 1.31^0S, 36.65^0N, Mashuuru meteorological station in Kajiado central area which is located at 2.10^0S, 37.10^0E, Magadi soda works in Kajiado west, located at 1.88^0S, 36.28^0E and Maasai rural trading centre Isinya in Kajiado east, located at 1.40^0S, 36.50^0E. The rainfall data were analyzed for a period of 43years (1970-2013). The stations were selected because of the availability of long term data and their presence within the different sub-counties in Kajiado County. Average monthly temperature for Kajiado East was also collected from KMS and analyzed.

4.2.4 Focus group discussion and key informant interviews

A total of four (4) focus group discussions (FGDs) were conducted separately with a gender parity (of eight men and eight women) from the sampled villages. The focus group discussions were conducted for the following reasons: (1) to triangulate and validate result from the household interview (2) to validate result from the vulnerability mapping of the study area with the Maasai pastoralists (3) to identify the challenges of the most vulnerable communities and together with the communities identify viable adaptation options. The pastoralists that participated in the FGD were selected with the help of the local leaders. Participants in the focus group discussions were household heads selected based on the number of years they have spent in the location and their main source of livelihood which is pastoralism. Focus group discussion created opportunity for further interaction with the community members and lead to verbal expression and opinions about climate change and its effect on the pastoralists' livelihood. The discussions captured the local knowledge on climate variability and its impacts on pastoralist communities, vulnerability, and adaptation and coping options to extreme climate events. Further discussions were held with a total of 30 key informants individually between November 2014 and March 2015. The key informants were selected from organizations in Kajiado County, Staff of the County meteorological department, local chiefs, village elders and drought monitors, community-based animal health workers, and opinion leaders.

4.2.5 Household interviews

Information on different aspect of the study was obtained through the administration of questionnaire on individual pastoralist households and community leaders. The information collected using the questionnaire included (1) demographic information of households; (2) socio-economic characteristics of individual households including resource endowments, sources of income and infrastructural status; (3) information on perception of Maasai pastoralist to climate change and variability (4) climate-related extreme events and their impacts on the pastoralist livelihood; (5) adaptation and coping strategies of households to climate change and climate variability. The information collected from the household interviews was further triangulated with FGDs, informal interviews and general observations.

4.3 Research approach

The study adopted a transdisciplinary research approach where the impact of climate change on Maasai pastoralist community is viewed in a holistic way. The three complexity of Transdisciplinarity (dynamic complexity, social complexity and generative complexity) was involved in the research process. Transdisciplinary research has two parallel processes which are the research process and the change process. The research process in transdisciplinary research involves investigating the current situation and articulating possible future situation. It support learning and knowledge integration and identifies stakeholders to understand their views. The change process in transdisciplinary research involves transformation of a society through mutual learning, knowledge integration and by involving all the stakeholders. Various sources of knowledge (table 4.1) both scientific and indigenous were integrated to address the research objectives of this study.

Table 4.1: Description of stakeholder involvement in the project

Stakeholders	Level and stage of involvement
Core researcher team (Research student, his supervisors and field assistants)	They were involved in project conceptualization, proposal development, coordination of other stakeholders, coordination of field work and development of project output such as PhD thesis, research journals, policy briefs and adaptation manual.
Research consultants (meteorologist, adaptation experts and statistician)	These are experts that have conducted similar research in similar ecosystem, they made contribution during proposal writing, data collection and analysis
Strategic actors (government organizations and NGOs working on climate change and climate change adaptation	They were involved in identifying climate challenges and designing research question, they were also involved in provision of information for analysis and also research validation
Local actors (Maasai pastoralist and administrative chiefs)	This group was involved in most stages of the research. They were involved in problem identification, project design, they provided information for analysis. They were involved in developing research recommendation and also validation of the result

The study adopted participatory, descriptive and inferential research design. The participatory design gives opportunity to every stake holder to participate in problem identification, problem analysis and problem solving. Descriptive approach allows for description of a given phenomenon while inferential research gives the researcher the ability to make inferences about the population using data collected from the population. The study incorporated both quantitative and qualitative research methodology by collecting data for both.

4.4 Study design

The field study was conducted in selected villages in Kajiado County. Kajiado County was purposively selected because it is one of the arid and semi arid lands in Kenya which is prone to extreme climatic events especially drought and dry spells. It also has high population of Maasai who practice pastoralism as their main source of livelihood and are affected by the negative impact of climate change and its extremes. The study used multistage sampling technique. Multistage sampling is a sampling technique in which large groups are further sub- divided into smaller, more targeted group for the purpose of surveying. In this study, multistage sampling was carried out by first purposively selecting Kajiado east sub-county for sampling. Then the sub-county was categorized on the basis of the five administrative wards. This was followed by random selection of communities for sampling. The distribution of communities selected and the number of households selected for sampling is presented in Table 4.2. The households in the communities were then listed from 1 to N (N = group size), and then systematic selection of the households were carried out. A random start was used in choosing the first household to be interviewed and the interview were conducted in every seventh household. Thus, the choice of the household interviewed was based on systematic sampling procedure (Prewitt, 1975). A total of 305 households were interviewed between November 2014 and February 2015.

To determine the sample size used in the study the following formula (Oremo, 2013) was employed:

$$S = X^2NP\ (1\text{-}P) \div d^2\ (N\text{-}1) + X^2P\ (1\text{-}P)$$

Where:

S = required sample size

X^2 = the table value of chi-square for 1 degree of freedom at the desired confidence level (95%) (3.841)

N = the population size

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

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

Based on 1800 Maasai pastoralist households in Kajiado east, a total of 56 villages and 305 Maasai pastoralist household were sampled in this study.

Table 4.2: Distribution of sampled villages in each ward

Wards	**Villages sampled and number of questionnaires sampled per village**	**Total number of household sampled per ward**
Kaputie North	Emampariswai (4), Enkileele (3), Enkirgirri (3), Ilkiushin (3), Ilpolosat (5), Isinya (8), Kekayaya (5), Kisaju, (8), Lenihani (3), Noosuyian (3), Ntipilikuani (3), Olepolos (3), Olkinos (3), Olmerui (5), Oloshaiki (2), Olturoto, (6), Ormoyi, (4).	69
Kitengela	Embakasi (8), Enkasiti (8), Kepiro (6), Kitengela (8), Korrompoi (7), Mbuni (7), Nado Enterit (5), Naserian (8), Nkukuon (5), Olooloitikoshi (5)	67
Sholinke	Embakasi (6), Enkutoto o mbaa (9), Kware (8), Nkukuon (6), Olooloitikoshi (9), Oloosirikon (8), Sholinke (6)	56
Kenyawa Poka	Arroi (8), Esilanke (5), Kenyawa (6), Kibini (4), Mashuuru (5), Noompaai, (6), Olgulului (5), Oltepesi (8), Poka (4), Sultan (5)	55
Imaroro	Arroi (4), Imaroro (4), Konza (6), Mbilin (6), Oibor Ajijik (4), Olekaitoriori (10), Olgulului (8), Oloibor Ajijik (7), Oltepesi (7), Wulu (8).	57`

4.5 Conceptual Framework

Adaptation to climate change refers to adjustment in natural or human system in response to actual or expected climatic stimuli. The Maasai community and relevant stakeholders were consulted in the process of designing this project. The conceptual framework Fig 4.1 shows a comprehensive and holistic approach to understanding the vulnerability of the Maasai pastoralist community to climate change and variability; and identifying viable adaptation options for the community through stakeholder involvement. The framework considered vulnerability as a function of exposure to climatic, sensitivity and adaptive capacity of the households; it involves the community and stakeholders in understanding the vulnerability to climate change by the pastoralist households and also understanding adaptation strategies adopted by pastoralist against climate change and variability.

The integration of various sources of knowledge from different stakeholders is desireable if we are to address the numerous threats the pastoral livelihood systems face as a result of climate change and variation. The resilience pathway is viewed as a process rather than a static state of a system. Households and communities that are able to use their adaptive capacity to manage stresses they are exposed to, and incrementally reduce their vulnerability are on a resilience pathway. Resilient communities have access to information and are able to participate in decision making that affect their lives. This study is framed to understand the climate stress and shock that trigger pressure on pastoral livelihood. It also contributes to an integrated understanding of the levels of vulnerability of Maasai pastoralist to climate change and variability. The study analyzed the specific adaptation and coping strategies that Maasai pastoralist are using in coping with climate-induced disturbances for more effective targeting of policies and adaptation programmes.

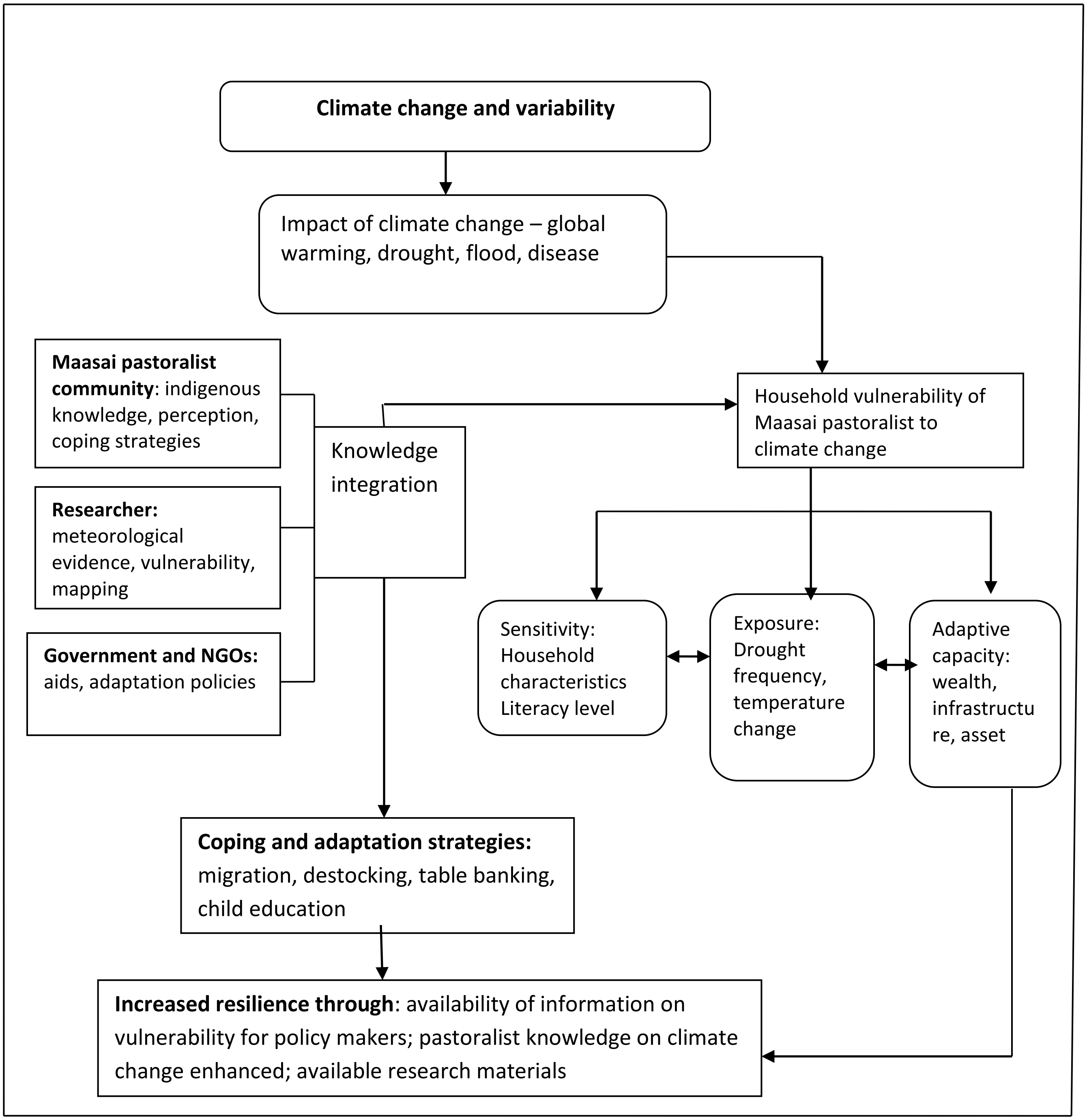

Figure 4.1: Conceptual framework

4. 6 Data processing and analysis

4. 6.1 Climate Data processing and analysis

4. 6.1.1 Estimation of missing climatic data

The World Meteorological Organization (WMO) standards for estimating missing data is that, the missing data of a station should be below 10% of the total records. The rainfall data collected from Kenya Meteorological service (KMS) shows that 3.2% of the rainfall data were missing. There are several techniques for estimating missing data including; Thiessen polygon method, Isohyetal method, the arithmetic means, the isopleths method, finite differencing method, Correlation and regression method. The missing data for the stations was estimated using the regression equation below:

y = a + bx --- (1)

Where y = dependent variable (predicted rainfall amount in the affected station)

x = independent variable (available rainfall data for the station)

a = intercept

b = regression coefficient

4. 6.1.2 Climate trend analysis

The seasonal and inter-annual rainfall characteristics and also temperature trend at the stations were presented using graphs, tables and charts. Analysis of inter-annual and seasonal components for the data was conducted to reveal general information for a time series within a year and between different years. It was also useful for comparing the general spatial and temporal variations among the input data series. Standard deviation and coefficient of variation (% C.V) was also calculated to reveal the degree of seasonal and inter–annual climate variation in the different station using the formula below.

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}}$$

x= sample mean average

n = sample size

S = standard deviation

% C.V = standard deviation/ mean-- (2)

4.6.1.3 Standardized Precipitation Index (SPI) calculation

The standardized precipitation index (SPI) was used to analyze drought severity in the study area between 1970 and 2013. SPI was designed to quantify precipitation deficit for multiple time scale (McKee et al., 1993). The SPI is calculated by dividing the difference between normalized seasonal precipitation and its long-term seasonal mean by standard deviation as follows:

$$SPI = \frac{Xij - Xim}{SD}$$

Where *Xij* = Seasonal precipitation value at jth station

Xim = Long term seasonal mean precipitation

SD = Standard deviation

This study used the McKee *et al*. (1993) SPI classification system (Table 4.3) to define drought intensity resulting from the SPI.

Table 4.3: SPI classification used in this study

SPI values	Classification
2.0	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-.99 to .99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 and less	Extremely dry

4.7 Vulnerability Analysis

This study analyzed vulnerability of Maasai pastoralist as a net effect of adaptive capacity, exposure and sensitivity.

Vulnerability = Adaptive capacity – (exposure + sensitivity) ------------------------------ (3)

The integrated vulnerability assessment method was used to analyze vulnerability of Maasai pastoralist to climate change. The method is in line with the intergovernmental panel on climate change IPCC (2012) definition of vulnerability as “the degree to which a system is susceptible or unable to cope with adverse effect of climate change, including climate variability and extremes, and vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity". When adaptive capacity of the pastoralist household is less than the sensitivity and exposure, the household becomes more vulnerable to climate change impacts and the reverse is also true, the higher the adaptive capacity, the less vulnerable the household to climate change impact. This method uses a combination of indicators to measure vulnerability by computing indices and weighted average for the selected indicators. The indicators used in this study were selected based on researchers' observation, literature review of published research done in pastoralists' communities and the opinion of the Maasai pastoralists communities in Kajiado County. Community involvement is important in selecting indicators for vulnerability analysis. This is because vulnerability to climate change is location specific.

The principal component analysis (PCA) was used to generate factor scores for calculating vulnerability index for the households. PCA is a technique for extracting from a set of variables, few orthogonal linear combinations of variables that most successfully explain common information (Deressa, 2010). In this study, the first principal component is the linear index of all the variables that captures the highest amount of information common to all variables.

The vulnerability index was determined based on three vulnerability components (adaptive capacity, exposure and sensitivity), the PCA method used was previously described by (Opiyo *et al.*, 2014). The vulnerability index of household was calculated using the equation below:

$$V_i = (A_1X_{1J} + A_2X_{2J} + \ldots\ldots\ldots + A_nX_{nj}) - (A_1Y_{1j} + A_2Y_{2j} + \ldots\ldots\ldots\ldots A_nY_{nj}) \text{ ------------ } (4)$$

Where V_i = vulnerability index

X_s = indicators for adaptive capacity

Y_s = indicators for exposure and sensitivity

A_s = First component score of each variable computed using PCA.

The values of X and Y were obtained by normalizing the values of vulnerability indicators (appendix 4) using their mean and standard deviations. In this study, Vulnerability index was calculated using 28 vulnerability indicators selected for adaptive capacity, exposure and sensitivity. Vulnerability index were generated for the 305 pastoralist household interviewed in 56 communities in Kajiado East. The average vulnerability index for each community and ward in Kajiado East was determined by calculating the mean vulnerability index for the communities (Appendix 3) and wards. The vulnerability of households was categorized into highly vulnerable households, moderately vulnerable households and less vunerable households. The percentage of households that fall into each of the vulnerable categories in the five administrative wards in Kajiado East was also calculated.

The study presented the level of vulnerability of households and Maasai communities in the study area in a map. The vulnerability maps showing the levels of vulnerability of Maasai pastoralist communities (highly vulnerable, moderately vulnerable and less vulnerable) in the five administrative wards in the study area was produced using Geographical Information System (GIS) software package ArcGIS 10.2. Focus group discussions and key informant interviews with Maasai pastoralist and stakeholder meetings were conducted in the study area to verify and validate the vulnerability maps produced in this study.

The level of influence of the indicators on vulnerability of the households was also analysed using the ordinal logistic regression model. The model is used when results are presented in ordinal scales, as in this study where vulnerability is categorized into (1) highly vulnerable (2) moderately vulnerable and (3) less vulnerable households.

The reduced form of ordinal logistics regression used in this study as described by Green (1997) is given as:

$$Y_j^* = X_j^i \beta + U_{ij} \quad \text{---} \quad (5)$$

Where Y = Level of vulnerability and involves ordered vulnerability categories, Y = 1 was given to highly vulnerable households, Y= 2 was given to moderately vulnerable households and Y= 3 was given to household less vulnerable households. Y* is the given state of vulnerability. The X_{ij} are the explanatory variables determining vulnerability level. β_s are parameters estimated and U_{ij} is the disturbance term.

4.8 Statistical analysis

The data obtained from this study was analyzed using both qualitative and quantitative approaches. Climate data (rainfall and temperature) were analyzed using descriptive analysis. Descriptive analysis carried out on the climate data included means, maximum and minimum values, climate trend graphs and charts. Data collected from household survey on perception of pastoralist on climate change, household characteristics and adaptation strategies to climate change and variability were also analyzed using descriptive statistics and presented in tables and charts.

The households' vulnerability was analyzed using principal component analysis (PCA) and regression analysis. The vulnerability indexes were categorized into highly vulnerable; moderately vulnerable; and less vulnerable. Ordinal logistic regression was used to determine indicators that significantly influence vulnerability in the study area. Quantitative analysis was carried out using Microsoft excel and Statistical Package (R) software. Vulnerability maps showing the vulnerability levels of administrative wards in the study areas were produced using GIS software package ArcGis 10.2.

Qualitative data analysis involves the ability to construct a coherent and explanatory account from data. This requires the ability to turn raw data into something that promotes understanding and increase knowledge that can be viable basis for transformation. Qualitative data collected in this study from focus group discussions and key informant interviews on perception of Maasai pastoralist on climate change, timeline analysis of climate events and adaptation strategies to climate change and its extremes were coded and analyzed using NVIVO statistical packages.

CHAPTER FIVE

ANALYSIS OF RAINFALL AND TEMPERATURE TRENDS IN KAJIADO COUNTY, KENYA

5.1 Introduction

Arid and semi-arid lands (ASALs) are particularly vulnerable to the impact of climate change and variability. This is due to highly erratic rainfall pattern that is having severe impact on pastoralism and rain-fed agriculture. If the condition continues as they are, impacts of the erratic rainfall resulting from climate change and variability are expected to further depress marginal lands that currently support livestock and crop production. In Kenya, the ASALs constitute about 80 percent of the total land surface area (Nyariki *et al*., 2002; Amwata 2013). The ASALs account for about 30 percent of the total national population and 50 percent of the total livestock population. They also account for vast amount of untapped natural resources (ROK, 2004; UNDP, 2010). Davis (2007) reported that livestock production contributes about 90 percent of the employment in ASALs and about 95 percent of family income and livelihood security. He noted in his valuation of pastoralism that the system goes beyond simple mode of livestock production. Pastoral system also includes consumption system that support a large global population and a natural resource management system that support a wide range of services and products that are of global value, such as biodiversity, tourism and raw materials.

In terms of rainfall, the ASALs in Kenya receive an annual precipitation of between 500 and 800mm, and lies within the ecological zone IV and zone V. Rainfall pattern in the ASALs have historically been identified with variability in water and fodder availability, influencing mobility and settlement patterns and leading to the development of pastoralism as the most suitable livelihood (Swift, 1998; Fratkin *et al*., 1999; Wasonga, 2009; Wasonga *et al*., 2010). It is expected that climate change and variability will alter weather patterns especially rainfall amounts resulting in increased severity and frequency of extreme climatic events (IPCC, 2014). Wasonga *et al*., (2010) argued that the effects of climate change and variability will be probably be the most acute for pastoralist and agro pastoralist especially those in Africa, including Kenya.

There seems to be a wide spatial and temporal variation in rainfall pattern in Kajiado County. Information on rainfall and temperature trends is important especially in the ASALs where rainfall and temperature is becoming increasingly unpredictable. Global circulation model predicts that climate change will increase temperature by about 4^0C and also cause variability in rainfall by up to 20% by the year 2100 (IPCC, 2014). Understanding this variation in climate parameters and its impact on livelihood pattern will be useful for resource allocation and adaptation planning in the County. This study therefore gives a comparative analysis of the rainfall trends in the different sub-counties in Kajiado County. It also analyzed temperatures trends in the study area over a period of 43years. This analysis will be useful for researchers and policy makers in taking evidence based decision in the county.

5.2 Results and discussion

5.2.1 Rainfall patterns in Isinya, Kajiado east sub-county from 1970-2013

The average monthly rainfall trends in Kajiado east is presented in Figure 5.1. The rainfall pattern shows a bimodal trend in annual rainfall characteristics. It depicts two main rainy seasons; the first and the long rainy season starts in March and peak in Aprils and declines towards May. The average monthly rainfall amounts for the long rains are 88.84mm, 135.49mm and 59.65mm for the months of March, April and May respectively. The short rainy season occurs in October to December. The amount of rain in the short rainy season is less than that of the long rains, giving an average monthly amount of 39.44mm, 92.10mm and 71.42mm for the months of October, November and December respectively. These results agree with those of ROK, (2002); ROK (2009); Opole, (2013) and Amwata, (2013). The average monthly rainfall for Isinya meteorological station is 51.01mm and six months of the year (February, June, July, August, September and October) had rainfall lower than the average. The lowest rainfall was recorded in the months of July, August and September with rainfall amounts of 13.7mm, 2.7mm and 20.4mm respectively. Opole (2013), in a study conducted in similar ecosystem also reported that the month of July had the lowest rainfall in the year.

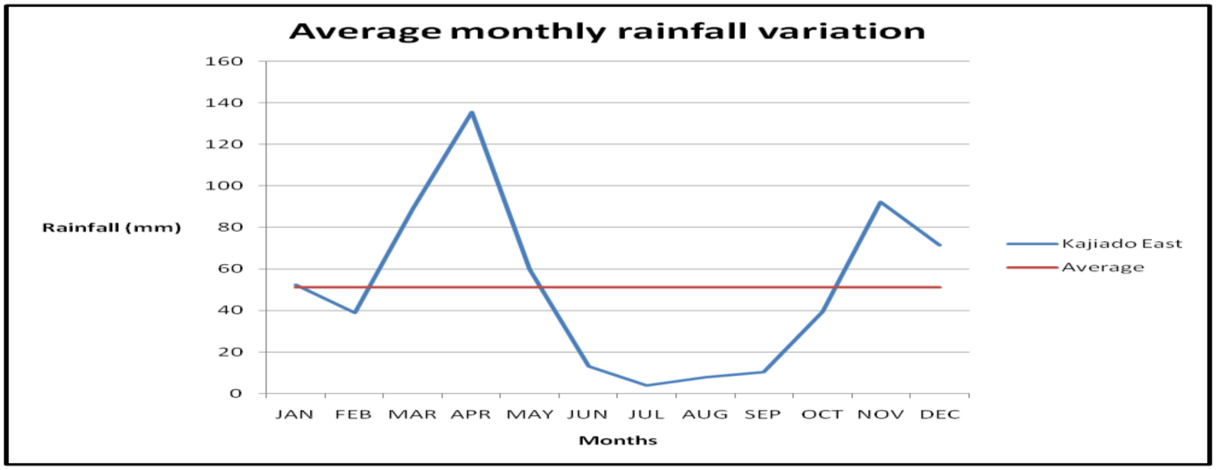

Figure 5.1: Average monthly rainfall pattern for Kajiado Maasai rural trade centre (Isinya Kajiado East)

Figure 5.2 shows the inter-annual rainfall for Isinya meteorological station, Kajiado east from 1970 – 2013. The Figure shows that the average annual rainfall for Isinya over the past 43 years (1970 – 2013) is 612.18mm. This is within the range of between 500mm and 1200mm reported for Kajiado County by ROK, (2009), but higher than the annual average rainfall of 458.9mm reported by Amwata (2013) for Kajiado County. Bekure *et al*., (1991), reported an average annual rainfall of between 500mm-900mm for semi-arid regions in Kenya. The station recorded a total of 23years that are above average and 20years below average. The driest years were 1973, 1975, 1976, 1984, 1999, 2000, and 2008 with rainfall of 348.9mm, 417.1mm, 324.0mm, 386.8mm, 474.5mm, 224.3mm and 492.8mm respectively. This finding agrees with findings of Orindi *et al*., (2007); ICPAC (2007) and Amwata (2013) that in Kajiado drought phenomenon has occurred during the years 1973, 1975, 1980, 1984, 1994, 2000 and 2008. The result also shows that the wettest year recorded over the period are 2001 (927.6mm), 1989 (922.7mm), 1997 (812.32mm) and 2010 (807.3mm). The result also show high variation in rainfall in recent decades, for example the year 2000 recorded the lowest rainfall of 224.3mm and this extreme drought was followed by the highest rainfall of 927.6mm recorded in 2001. Such extreme variation in rainfall affect rainfall dependent livelihood such as pastoralism with subsequent increase in vulnerability of pastoralists to climate change and variability (Opole, 2013). Several studies (Omolo, 2010; Opiyo *et al*., 2014; Kagunyu 2014) conducted in ASALs of Kenya have reported that increased variation in rainfall pattern in recent years is affecting the resilience of pastoralists living in the arid and semi-arid lands of Kenya.

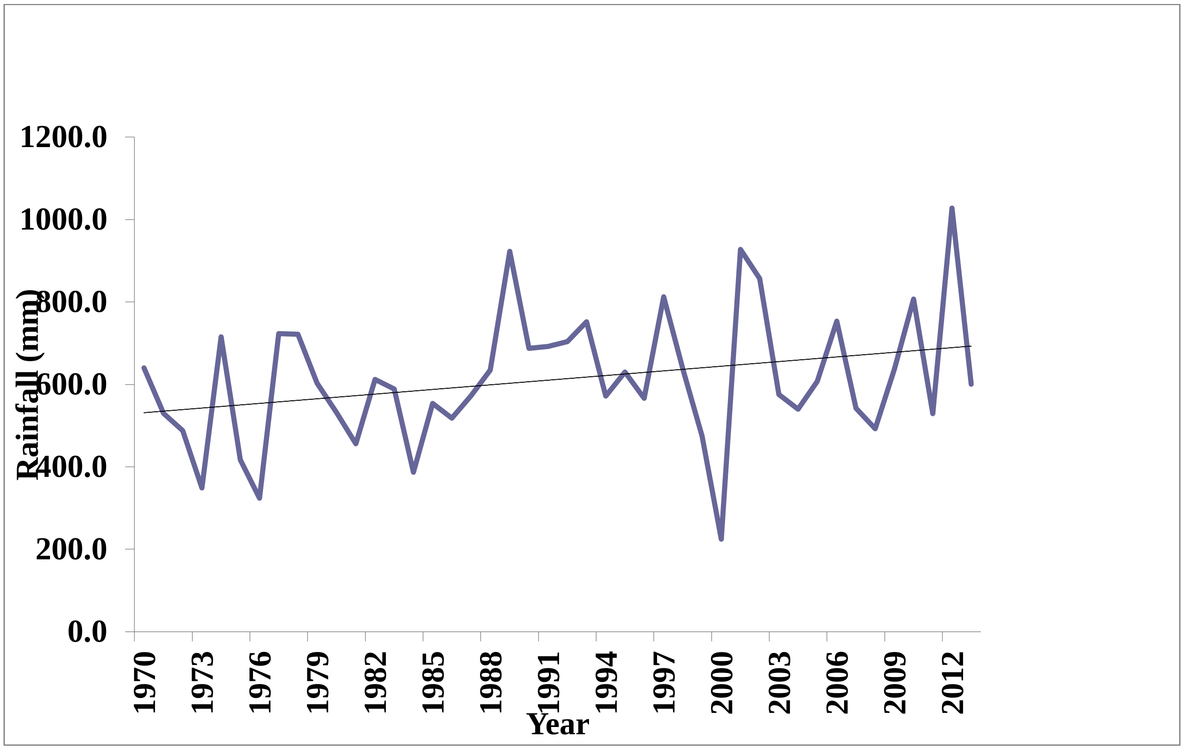

Figure 5.2: Inter-Annual rainfall variation for Kajiado Maasai rural trade centre (Isinya, Kajiado East) from 1970 – 2013

5.2.2: Rainfall pattern in Ngong, Kajiado North from 1970-2013

The average monthly rainfall trend for Ngong meteorological station is presented in figure 5.3. The station has an average rainfall of 79.5mm in a year. It shows a bimodal rainfall seasonal trend with the long rains occuring in March, April and May with rainfall amounts of 100.14mm, 224.02mm and 154.03mm respectively. The short rainy season is in the months of October, November and December with the rains extending to January. The short rainy season records lower rains of 55.75mm, 140.00mm, 88.44mm and 57.98mm for October, November, December and January respectively. The result of this research agrees with the findings of Opole (2013), who reported a peak rainfall of 88.8mm, 175.9mm and 147.9mm for March, April and May in Ngong respectively. It also agrees with Ogallo (1993) and ROK, (2009), which reported that long rains (March to May) contributes between 50% to 70% of the annual rainfall and the short rains about 20%. The driest months of the year are June, July, August and September with average rainfall of 32.23mm, 13.72mm, 21.01mm and 20.60mm respectively.

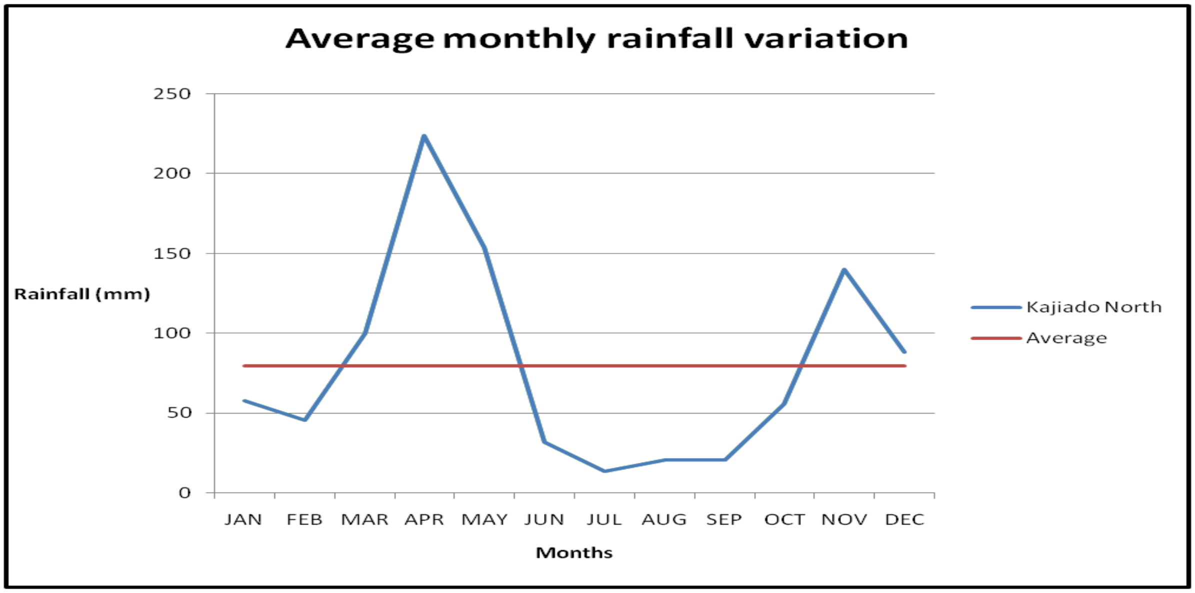

Figure 5.3: Average monthly rainfall trend for Ngong forest station (Ngong, Kajiado North)

The inter-annual rainfall variation for Ngong over the past 43years (1970 to 2013) is presented in Figure 5.4. Ngong had an average annual rainfall of 979.20mm. A total of 16 years had rainfall higher than the average while 27years had rainfall lower than the average. The longest dry spell was between 1971 and1976 which was followed by heavy rains in 1977 (1487.25mm) and 1978 (1282.13mm) and also the dry spell of 1983 to 1987 was followed by the longest wet period of 1988 (1312.5mm), 1989 (1163.73mm) and 1990 (1188.06mm). Generally 1984 (382.8mm) had the driest year followed by 2000 (470.2mm) and 1976 (529.93mm). This confirms the reports of UNEP and GOK (2000); GOK (2005); Orindi *et al*., (2007); ICPAC (2007) and Amwata (2013) that severe drought occurred in Kajiado County in these years. The highest amount of rainfall was recorded in the years 1977, 1997, 2006, 1988 and 1981, with rainfall amounts of 1487.25 mm, 1473.9 mm, 1349.4 mm, 1312.5 mm and 1310.11mm respectively. The trend shows that a year of heavy rain is usually preceded by one or two years of low rains. Generally the average rainfall in Ngong is higher than that of the other stations in Kajiado County studied in this research. The study also shows that rainfall pattern in Kajiado is strongly influenced by altitude with the high areas around Ngong receiving high rainfall.

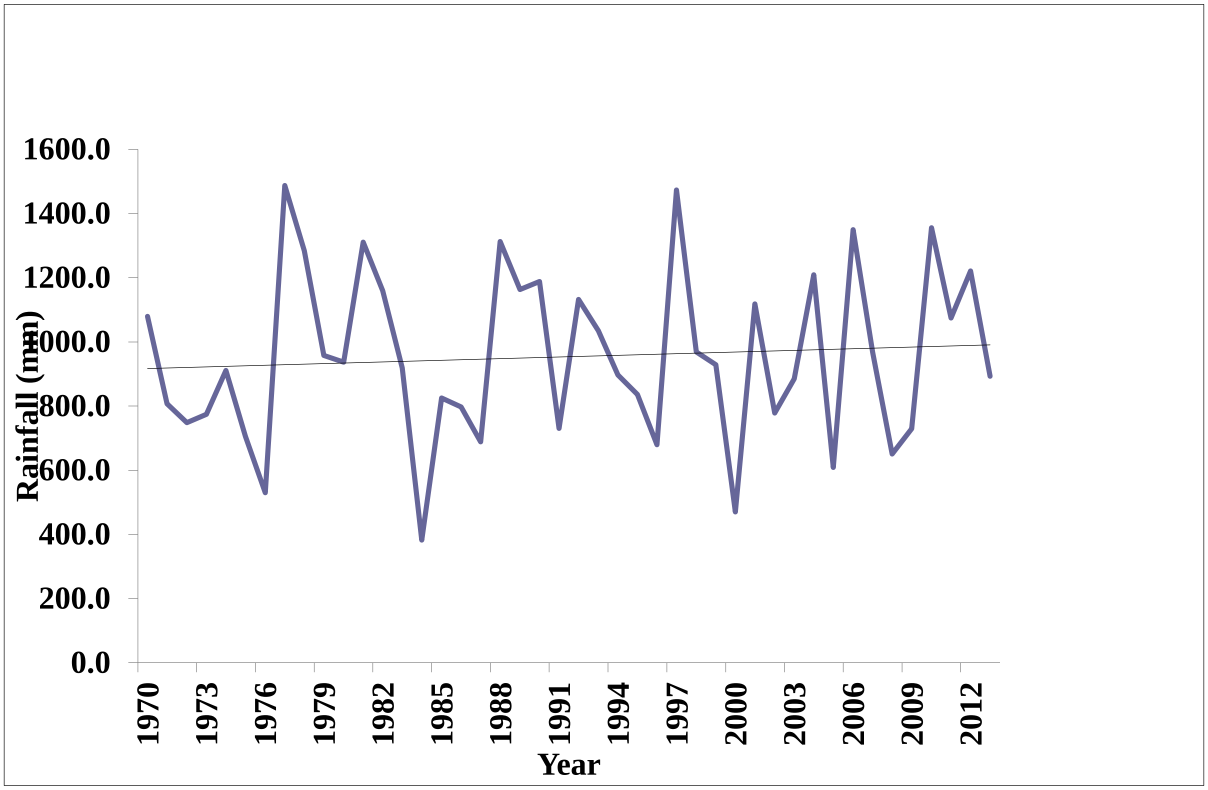

Figure 5.4: Inter-Annual rainfall variation for Ngong Division meteorological station (Ngong, Kajiado North) from 1970 – 2013

5. 2.3 Rainfall pattern in Magadi Kajiado west from 1970 to 2013

The average monthly rainfall trend in Magadi area (Figure 5.5) shows that Magadi area is the driest part of Kajiado County with an average monthly rainfall of 37.5mm. This according to Bukure *et al*. (1991) classifies Magadi as one of the arid regions of Kajiado, making it unsuitable for rain-fed agriculture. Amwata (2013) reported that low amount of rainfall and its erratic distribution prevent sustainable cropping in Magadi area for most part of the year. Magadi also shows a bimodal rainfall pattern with the long rains mainly in March (75.77mm) and April (96.71mm). The short rains are mainly in December and January with a rainfall of 45.74mm and 52.81mm respectively. The months of June, July, August and September are the driest months of the year with rainfall of 5.27mm, 4.59mm, 3.84mm and 11.53mm respectively. The rainfall pattern in arid areas like

Magadi has developed pastoralism as the more suitable source of livelihood (Swift, 1988; Fratkin *et al*., 1999; Wasonga 2009).

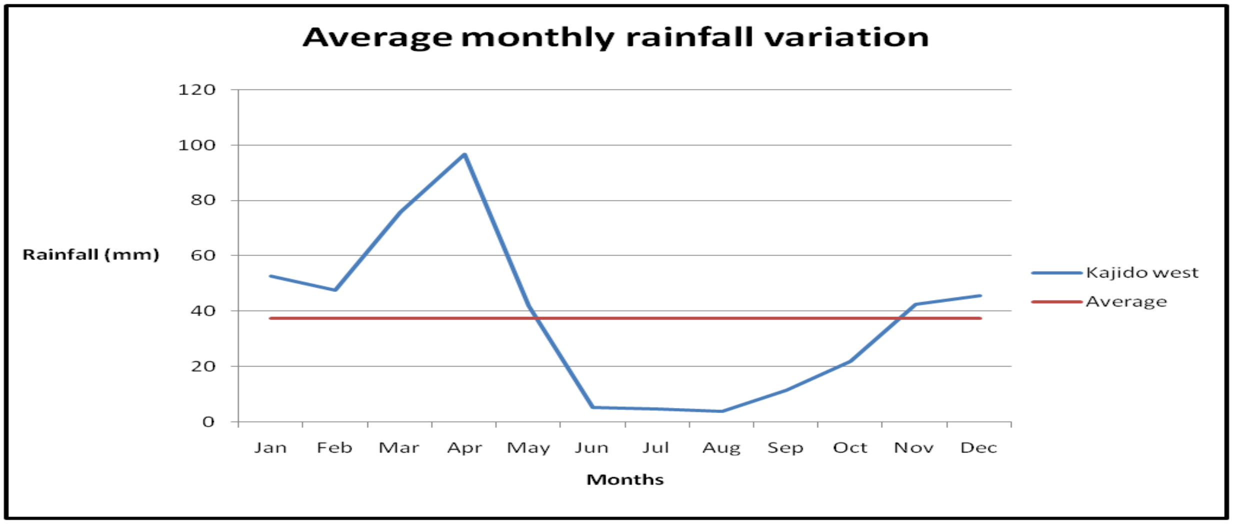

Figure 5.5: Average monthly rainfall trend for Magadi soda work meteorological station (Magadi, Kajiado west)

The graph (Figure 5.6) on inter-annual rainfall characteristics shows that Magadi has an average annual rainfall of 450.05mm per year, this compares with annual average of 490mm reported by Opole (2013) and confirms Magadi as one of the arid regions in Kenya (Bekure *et al*., 1991). A total of 20years had rainfall lower than the average, while 24years had annual rainfall higher than the average annual rainfall. The period of this research (1970 to 2013) shows that only 3years; 1970 (685.2mm), 1977 (640.3mm) and 1989 (673.4mm) had rainfall higher than 600mm per year. This confirms the reports of Orindi *et al*., (2007) and Action Aid (2009), that since 1990 the rate of occurrence of drought in some part of Kajiado County has increased to every two to three years. The years with the poorest rainfall are 1976 and 1984 with rainfall amounts of 230.3mm and 296.00mm respectively.

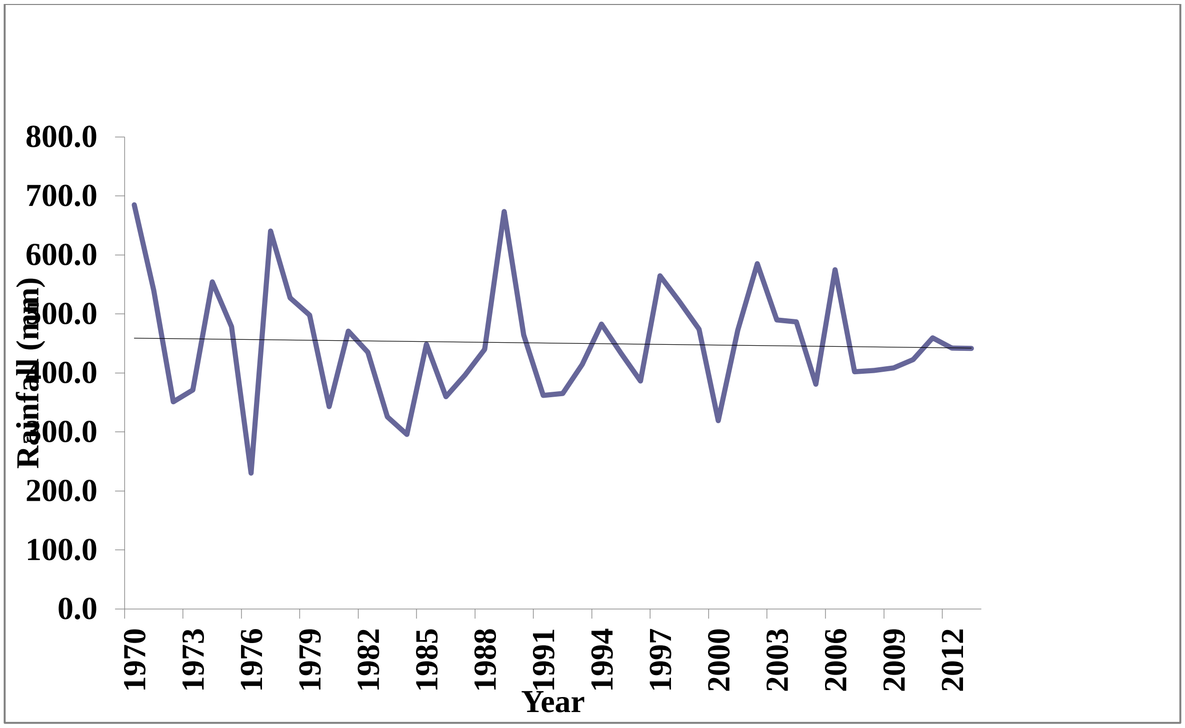

Figure 5.6: Inter-Annual rainfall variation for Magadi Soda Works station (Magadi, Kajiado West) from 1970 – 2013

5.2.4 Rainfall pattern in Mashuuru Kajiado central from 1970 - 2013

The average monthly rainfall pattern for Mashuuru, Kajiado Central is presented in Figure 5.7. Mashuuru meteorological station also has bimodal rainfall trend with two distinct rainy seasons. Generally the year starts with a short dry season in January (52.0mm) and February (31.21mm). This is followed by a long rainy season in March, April and May with rainfalls values of 66.70 mm, 139.51mm and 108.87mm respectively. The driest months of the year are June, July, August and September with rainfall values of 25.49mm, 11.63mm, 11.67mm and 15.53mm respectively. The short rainy period is in the months of November and December with rainfall values of 101.45mm and 66.18mm. The average rainfall for the year in Mashuuru is 56.21mm and only 5months of the year (March, April, May, November and December) have rainfall higher than the average. The rainfall trend for Mashuuru in this research concur with the findings of Opole (2013) who reported peak rainfall of 144.6mm in April and a minimum of 10.5mm in July for Mashuuru region in Kajiado County.

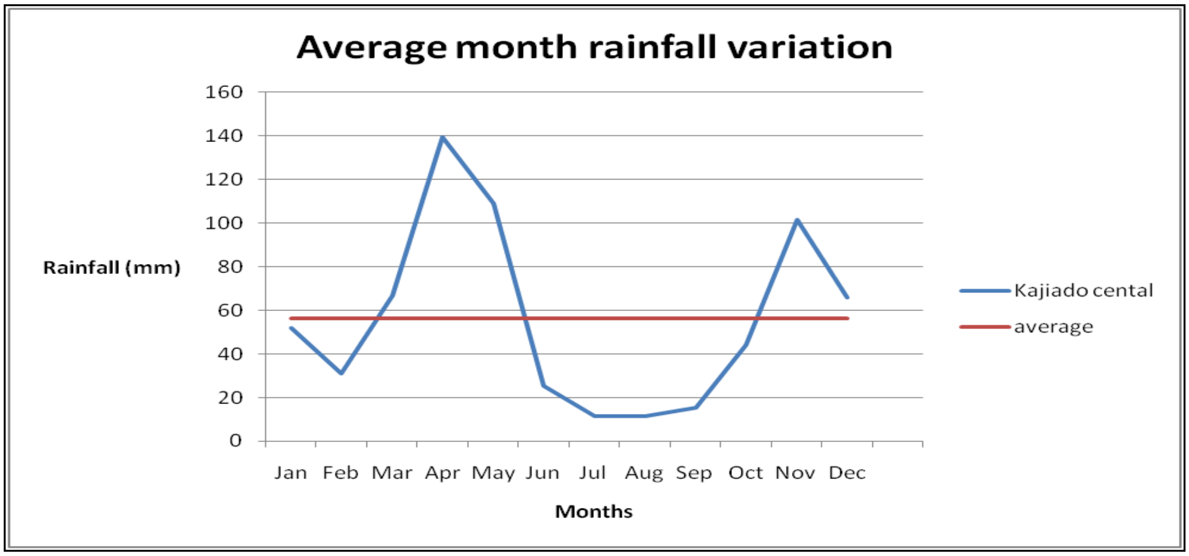

Figure 5.7: Average monthly rainfall trend for Mashuuru meteorological station (Mashuuru, Kajiado Central)

The inter-annual rainfall trends (Figure 5.8) for Mashuuru meteorological station from 1970 to 2013 shows that Mashuuru area has an average annual rainfall of 674.7mm which confirms it as one of the semi-arid areas in Kenya (bekure *et al*., 1991). Figure 5.8 show that a total of 25year had annual rainfall lower than the average while 19years have rainfall values higher than the average. The years 1977, 1998 and 2001 had the highest rainfall values of 1111.80mm, 1063.50mm and 1040.10mm respectively and only the three years had rainfall values higher than 1000mm per year. A total of five years 1975 (423.00mm), 1976 (419.10mm), 1984 (370.60mm), 1996 (453.60mm) and 2000 (371.50mm) had rainfall lower 500mm in a year. This agrees with UNEP and GOK (2000) that in Mashuuru drought events were recorded in 1975/76, 1984, 1994, 1996 and 2000. The year 1972 to 1976, 1983 to 1985, 1990 to 1996, 2003 to 2005 and 2007 to 2009 recorded the highest spell of dry seasons.

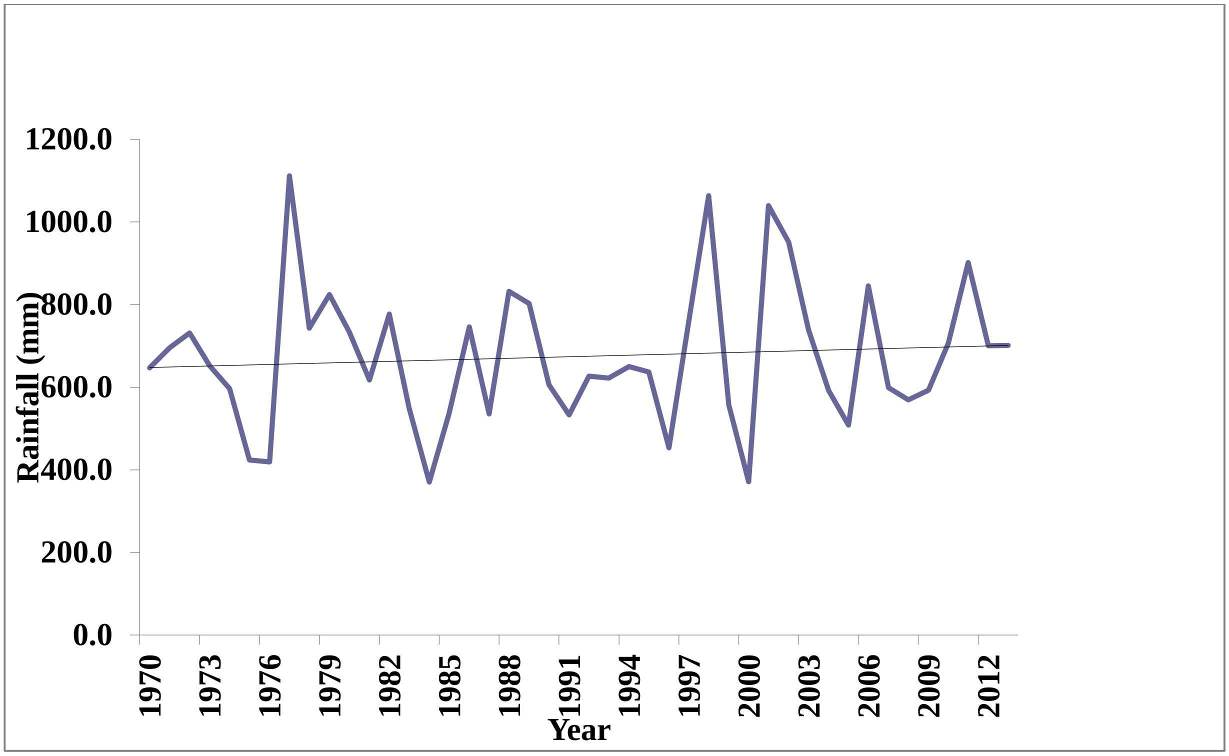

Figure 5.8: Inter annual rainfall variation for Mashuuru meteorological station (Mashuuru, Kajiado central) from 1970-2013

5.3 Rainfall variation in Kajiado County

5.3.1 Average monthly and seasonal rainfall variation in Kajiado County

Figure 5.9 shows the seasonal and monthly rainfall variation for the four stations considered in this research. The figure shows a bi-modal rainfall pattern in all the stations, confirming the assertions of Bekure et al., 1991, Ogallo, 1993, GOK, 2009a, GOK, 2000 and Opole, 2013 that Kajiado County has two rainy seasons, the long and the short rains. The long rainy season begins in March for all the stations and ends in May, while the short rainy season generally starts around October and ends in December. Ngong has the highest average monthly rainfall of 79.5mm followed by Mushuuru (56.21mm), Isinya (51.01mm) and least for Magadi (37.5mm). The rainfall pattern in Kajiado County is strongly influenced by altitude with the high areas around Ngong receiving high rainfall when compared to low areas around Magadi as reported by (Bekure *et al*., 1991; GOK, 2000 and Amwata, 2013). Generally, the long rainy season reaches its peak in April with Ngong, Mashuuru, Isinya and Magadi having rainfall amounts of 224.02mm, 139.51mm, 135.49mm and 96.72mm respectively. The amount of rainfall in high altitude areas of Ngong is more than twice that of the low areas of Magadi. The short rains starts in Kajiado County in the month of October and reach its peak in November with Ngong having a rainfall amounts of (140mm) in November, followed Mushuuru has (101mm) and Isinya (92.18mm). The late rains start around December (45.75mm) in Magadi and reach its peak in January (52.81mm). Generally the months of June, July, August and September are the driest months in Kajiado County with Magadi having a rainfall of 5.27mm, 4.59mm, 3.84mm and 11.53mm for the months of June, July, August and September respectively.

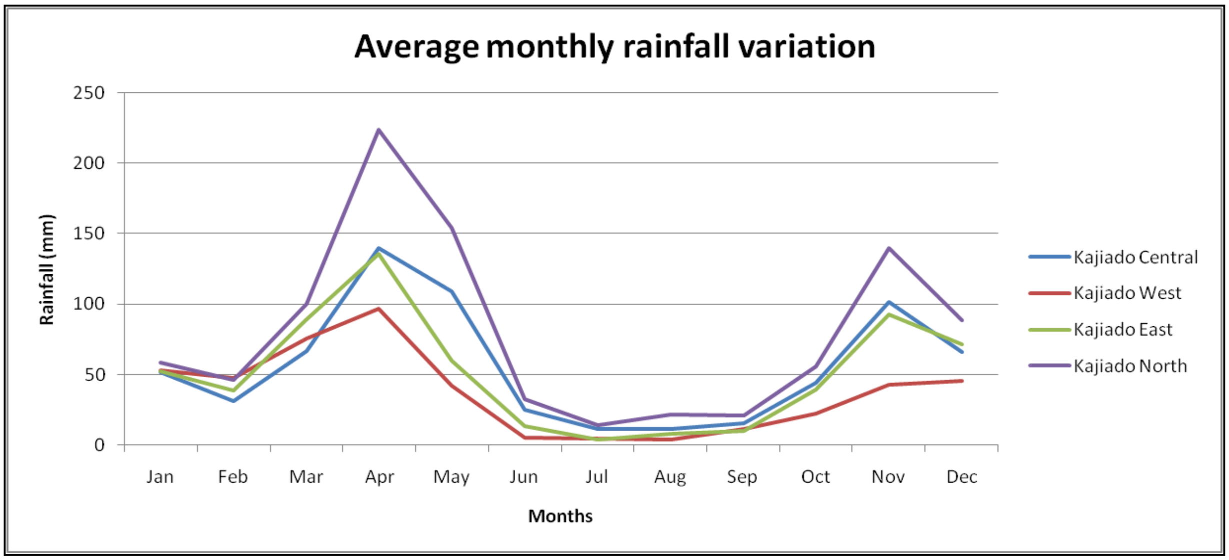

Figure 5.9: Average seasonal and monthly rainfall variation for the four stations

The seasonal variability for the four stations is presented in Table 5.1. The long rains (March to May) shows that Ngong station has a coefficient of variation (CV %) of 45%, Magadi has a CV% of 39.5%, Isinya has a CV% of 39.4% while Mashuuru has a CV% of 37.4%. Ngong has the highest CV% while Mashuuru has the lowest CV% for the long rains. The short rains show that Ngong has a CV% of 43.7%, Magadi has a CV% of 42.7%, and Isinya has 50.7% while Mashuuru has a CV% of 48.4%. The table shows that Isinya has the highest CV% for the short rains and Magadi has the lowest CV%. Generally with the exception of Ngong station, the coefficient of variation in Magadi, Isinya and Mashuuru are higher during the short rains (March to May) than during the long rains (October to November), agreeing with the reports of Herrero *et al*. (2010) and Opole (2013) that in Kajiado region, there is higher variability during the short raining season compared to the long raining season.

Table 5.1: Seasonal rainfall variability levels in the four stations

	Station							
	Ngong MS (KN)		Magadi MS (KW)		Isinya MS (KE)		Mashuuru MS (KC)	
	Long rains	Short rains	Long rains	Short rains	Long rains	Short rains	Long rains	Short rains
Mean	478.2	284.2	214.6	110.4	284.0	203.0	315.1	211.8
Standard deviation	215.0	124.1	84.7	47.1	111.9	102.9	118.0	102.5
CV%	45.0	43.7	39.5	42.7	39.4	50.7	37.4	48.4

5.3.2 Spatial and inter-annual rainfall variation in Kajiado County

The table on inter-annual and spatial variability for Kajiado County (Table 5.2) shows a wide spatial variation in rainfall in Kajiado County. Kajiado north represented by Ngong has the highest average annual rainfall of 979.2mm followed by Kajiado central (Mashuuru) having average rainfall of 674.5mm, Kajiado east (Isinya) has an average annual rainfall of 612.2mm while the least average annual rainfall was recorded in Kajiado west (Magadi) having average annual rainfall of 450.6mm. The average annual rainfall in Kajiado north (Ngong) is twice that of Kajiado west (Magadi), this confirms Magadi region as one of the arid area in Kenya and highly susceptible to drought. The result also showed that there was no significant difference in rainfall trend ($P>0.05$) for all the stations. The CV% is highest for Ngong (27.5%), followed by Isinya (26.4%) and Mashuuru having (25.5%) and lowest for Magadi (21.5%), this agrees with Opole 2013 that variation reduces with aridity of the area.

Table 5.2: Inter-Annual and spatial variability between the four stations

	Station			
Statistic	Ngong MS (KN)	Magadi MS (KW)	Isinya MS (KE)	Mashuuru MS (KC)
Mean(mm)	979.2	450.6	612.2	674.5
Standard Deviation	268.4	96.8	161.3	171.7
CV%	27.5	21.5	26.4	25.5
P-value	0.93	0.76	0.90	0.92

Inter-annual data shows no significant variation in rainfall trend ($P<0.05$) between 1970 and 2013.

5.4 Drought pattern in Kajiado County

The result of standardized precipitation index (SPI) values for the long rainy season (March-May) and the short rainy season (October to December) for a period of 43years (1970 -2013) is presented in Table 5.3. A total of twenty (20) years have negative SPI values for the long rains, while twenty three (23) years have negative values for the short rains. The long rainy season recorded extreme drought in three years 1973, 1984 and 2000 with SPI values of (-2.48, -2.77 and -2.82) respectively. Also moderately dry season was recorded in 1976 with a SPI value of -1.13. The short rainy season recorded two years 1970 and 1981 of extreme drought with SPI values of (-2.33 and -2.18) respectively. The short rains also recorded one year of severe drought in 1975 with a SPI value of -1.53 and five years 1972, 1973, 1976, 1980 and 2005 of moderate drought with SPI values of (-1.14, -1.06, -1.13, -1.27 and -1.36) respectively. The findings of this study agrees with Camberlin and Philippon, (2002) who noted that the long rainy seasons are more reliable than the short ones in ASALs regions.

The result shows that six years (1971, 1972, 1973, 1975, 1976 and 1979) had negative SPI values between (1970 and 1979) for the long rains and six years (1970, 1972, 1973, 1975, 1976 and 1979) had negative SPI values between (1970 and 1979) for the short rains. Four years (1982, 1983, 1984 and 1978) of negative SPI values were recorded between 1980 and 1989 for the long rains and six years (1980, 1981, 1983, 1985, 1987 and 1988) of negative SPI values were recorded between 1980 and 1989 for the short rains. The result show four years (1993, 1994, 1997 and 1999) of negative SPI values were recorded between 1990 and 1999 for the long rains, and also four years (1990, 1993, 1995, and 1996) of negative SPI values for the short rains between 1990 and 1999. The year 2000 to 2011 was the driest period reported in this study. Six (6) years (2000, 2004, 2007, 2008, 2009 and 2011) of negative SPI value were recorded for the long rains and seven (7) years (2000, 2003, 2004, 2005 2007, 2008 and 2010) were recorded for the short rains. Several studies (Mutai and Ward 2000; Howden 2009; Wasonga 2009; Wasonga et al., 2010; and Amwata 2013) have reported significant reduction in rainfall amounts especially during the short rainy season in the ASALs of Kenya. This report also confirms the findings from the FGDs where discussants reported increase in drought events in the last 15years.

Results of annual drought severity from 1970-2013 (Table 5.4) show that a total of 21years has negative SPI values. The study area experienced severe and extreme drought in the year 1976 and 2000 with SPI values of -2.03 and -3.09, respectively; with the year 2000 being the driest year reported in this study. Six years (2000, 2003, 2004, 2007, 2008 and 2011) have negative SPI values between 2000 and 2011. The increasing severity and frequency of drought occurrence in Kajiado County is an indication that the region is getting drier reflecting the observed climate change in the ASALs of Kenya.

Table 5.3 Drought severity for the long rains (March to May) and short rains (October to December) in Kajiado County between 1970 and 2013

Long rains (March to May)			Short rains (October to November)		
Year	SPI	Drought Classification	Year	SPI	Drought Classification
1971	-0.40	Near normal	1970	-2.33	Extremely dry
1972	-0.19	Near normal	1972	-1.14	Moderately dry
1973	-2.48	Extremely dry	1973	-1.06	Moderately dry
1975	-0.02	Near normal	1975	-1.53	Severely dry
1976	-1.13	Moderately dry	1976	-1.13	Moderately dry
1979	-0.41	Near normal	1979	-0.61	Near normal
1982	-0.96	Near normal	1980	-1.27	Moderately dry
1983	-0.34	Near normal	1981	-2.18	Extremely dry
1984	-2.77	Extremely dry	1983	-0.77	Near normal
1987	-0.07	Near normal	1985	-0.45	Near normal
1993	-0.67	Near normal	1987	-0.50	Near normal
1994	-0.34	Near normal	1988	-0.53	Near normal
1997	-0.19	Near normal	1990	-0.04	Near normal
1999	-0.43	Near normal	1993	-0.38	Near normal
2000	-2.82	Extremely dry	1995	-0.40	Near normal
2004	-0.24	Near normal	1996	-0.45	Near normal
2007	-0.74	Near normal	2000	-0.3	Near normal
2008	-0.76	Near normal	2003	-0.02	Near normal
2009	-0.67	Near normal	2004	-0.09	Near normal
2011	-0.63	Near normal	2005	-1.36	Moderately dry
			2007	-0.8	Near normal
			2008	-0.1	Near normal
			2010	-0.03	Near normal

Source: Author’s compilation

Table 5.4 Annual drought severity (January to December) in Kajiado County between 1970 and 2013

Year	SPI	Drought classification
1971	-0.44	Near normal
1972	-0.72	Near normal
1973	-1.81	Near normal
1975	-1.24	Moderately dry
1976	-2.03	Severely dry
1980	-0.42	Near normal
1981	-0.95	Near normal
1983	-0.05	Near normal
1984	-1.48	Moderately dry
1985	-0.27	Near normal
1986	-0.51	Near Normal
1987	-0.15	Near normal
1994	-0.16	Near Normal
1996	-0.18	Near Normal
1999	-0.8	Near normal
2000	-3.07	Extremely dry
2003	-0.13	Near Normal
2004	-0.37	Near Normal
2007	-0.35	Near Normal
2008	-0.69	Near Normal
2011	-0.44	Near Normal

Source: Author’s compilation

5.5. Temperature trends in Kajiado Countybetween 1970 and 2013

Temperature trend are analyzed to provide a scenario of temperature variability in the study area. The Results presented in Figure 5.10 show an increasing trend for average annual, average maximum temperature (Tmax) and average minimum temperature (Tmin). Overall, a rise in minimum (1.41^{0}C), maximum (0.47^{0}C) and average (0.94^{0}C) was observed between the year 1970 and 2013 in the study area. This confirms the effect of global warming in Kajiado County. Kenya Meteorological Department (KMD) reported that the trend of minimum temperature from 1960 has been increasing by 0.8-2.0^{0}C, while the maximum temperature has been increasing by 0.1-0.7^{0}C (GOK, 2010). The study also agrees with the IPCC (2014) report which predicted an average temperature increase of 0.2^{0}C per decade in Kenya. The results are also consistent with previous reports in the region by Opiyo, (2014); Amwata, (2013); King'uyu *et al*., (2000) which all reported increasing temperature over the years in arid and semi-arid lands of Kenya. Studies from Omondi *et al*., (2013) and Collins (2011) reported a general increasing warming temperature in ASALs in Kenya; they reported that the increasing temperature is particularly higher in the night and cold extreme in the night are decreasing in the horn of Africa region.

The results also shows that the years 2000, 1987, 2009, 1997 and 2011 recorded the highest annual temperature of 25.84^{0}C, 25.58^{0}C, 25.53^{0}C, 25.46^{0}C and 25.43^{0}C respectively. The years 1989, 1978, 1985, 1974 and 1979 had the lowest annual temperature of 23.92^{0}C, 24.08^{0}C, 24.21^{0}C, 24.35^{0}C and 24.35^{0}C respectively. These results generally show a clear changing temperature pattern at the local level and confirm that global warming can be observed even at the local scale. The result on average monthly temperature for Kajiado County shows that the month of March has the highest average monthly temperature of (21.15^{0}C) followed by February (20.77^{0}C) and April (20.45^{0}C) respectively. The months of July, August and June had the lowest temperatures of 17.18^{0}C, 17.49^{0}C and 17.98^{0}C respectively. The result is also consistent with Collins (2011) which indicates that rapid warming from 1979 onward is experienced in Kenya.

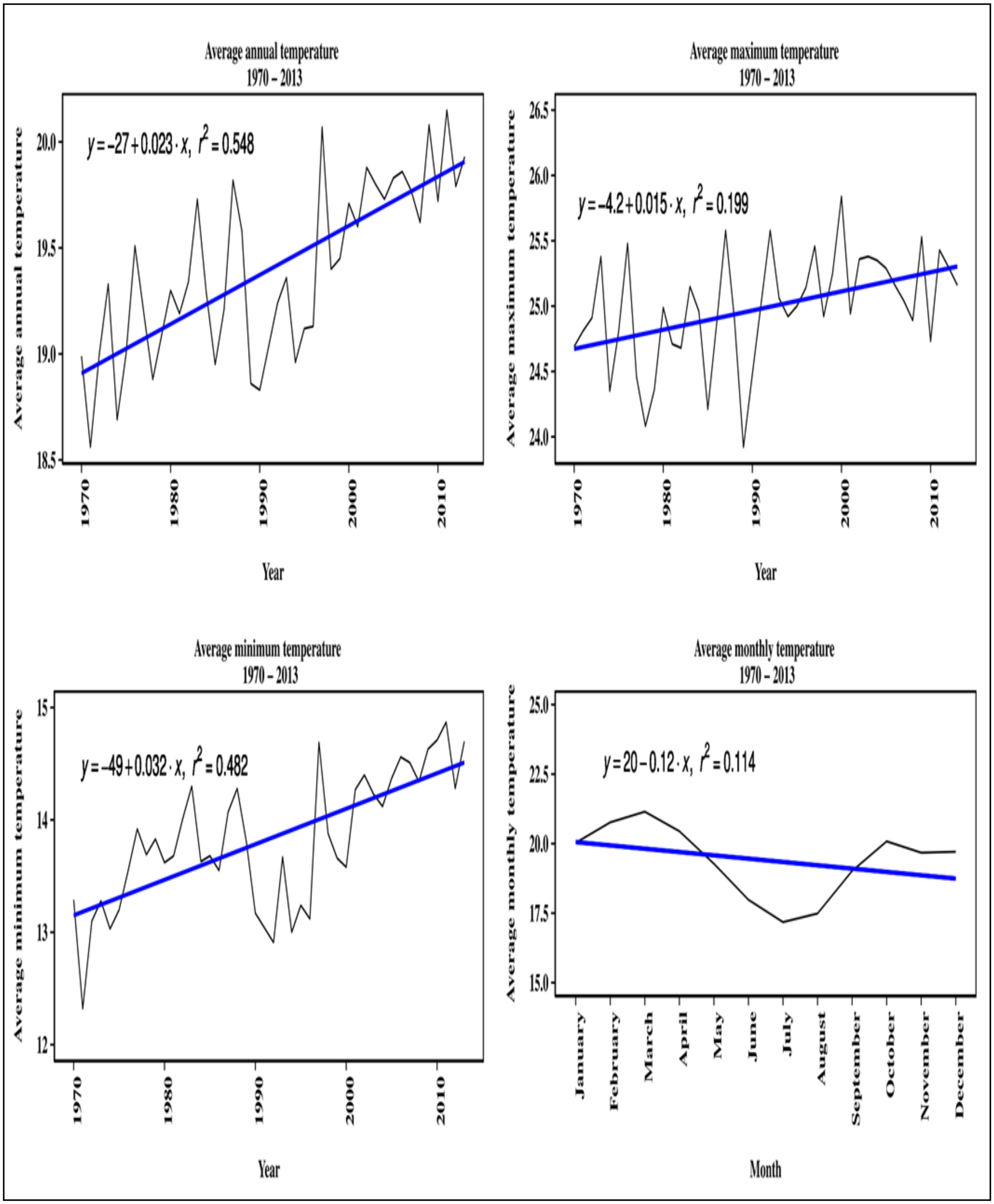

Figure 5.10: Trend analysis of temperature in Kajiado East from 1970-2013

5.6 Long term relationship between rainfall and temperature in Kajiado County

The correlation between monthly rainfall and monthly minimum and maximum temperature over a period of 43years (1970-2013) in Kajiado County is presented in Table 5.5. The values for rainfall and temperature in the table reflect the correlation between the climate parameters and they range between -1 to +1. A negative value shows that the variables are inversely correlated and they change in opposite direction to each other. Likewise, positive value shows that the variables are directly correlated and change in the same direction to each other.

Results showed that all the months of the year with the exception of August have a negative rainfall correlation with maximum temperature. This means that the higher the maximum temperature, the lower the rains. The months of January, February, October and December were significant at ($P<0.05$). The months of March and November were also highly significant at ($P<0.01$). The results revealed an interesting pattern between the correlation of the short rains (October, November and December) and the maximum temperature. The result showed that the months of the short rainy season (October-December) were all significantly negatively correlated with the maximum temperature. This means that increase in maximum temperature can have a significant effect on rainfall during the short rainy season. The result agrees with Camberlin *et al.*, (2001) who reported a significant correlation between the short rains and maximum temperature. It however negates the findings of Opiyo (2014) who reported a positive correlation between maximum temperature and the short rains in northern Kenya. The result also revealed a positive correlation between the minimum temperature and rainfall in the study area for all the months with the exception of February. However, only the month of December showed significant correlation at ($P<0.05$).

Table 5.5 Correlation of rainfall amount and the minimum and maximum temperatures for each monthin Kajiado County

	Temperature				Rainfall	
	Max Temp	p-value	Min Temp	p-value	Mean	SD
January	-0.3717*	0.0141	0.1999	0.1986	52.2	64.8
February	-0.3287*	0.0314	-0.0213	0.8922	39.2	42.6
March	-0.507**	0.0005	0.1219	0.436	87.9	70.9
April	-0.1759	0.2592	0.0166	0.9157	137.3	82.3
May	-0.0828	0.5978	0.2494	0.1068	58.7	55.3
June	-0.1489	0.3416	0.2142	0.1679	12.7	18.1
July	-0.1077	0.4919	0.2411	0.1193	3.8	6.9
August	0.2440	0.1149	0.0156	0.9207	7.5	10.8
September	-0.1435	0.3585	0.1972	0.2049	10.3	12.2
October	-0.4723*	0.0014	0.1972	0.205	38.3	35.8
November	-0.631**	0.0059	0.2080	0.1806	92.9	57.6
December	-0.2818*	0.0672	0.3026*	0.0486	69.6	58.6

*significant at ($P<0.05$); **significant at ($P<0.01$)

5.7 Annual rainfall and livelihood pattern in Kajiado County

The result from this study shows that there is high spatial variation in annual rainfall in Kajiado County. The annual rainfall in Kajiado County varies from an average of 979.2mm in Ngong to 450.6mm in Magadi. Rainfall is one the critical climatic factors that determine the livelihood pattern of rural dwellers in Kenya. Agricultural activities follow rainfall patterns in Kenya. Rain-fed agriculture, which provides food for the populace and represent a major share of Kenya’s economy follow precipitation pattern closely (United Nations Environmental Programme, 2008). Therefore, short-term as well as long-term variations in rainfall patterns have significant effects on crop and livestock farming in Kenya (IPCC, 2007). Results from this study shows that drought and dry spell is a major challenge in Kajiado County and the frequency of occurrence of drought has been increasing in recent decades.

This study further confirms that pastoralism and agro pastoralism are still very crucial livelihood options in the arid and semi-arid lands of Kajiado County. Several reports (Omolo, 2010; Silvestri *et al*., 2012; Osano *et al*., 2013) emphasized the importance of pastoralist system in the rangeland of Kenya. Pastoralism gives opportunity for pasture regeneration through seasonal transhumance movement giving time for pastures to regenerate; seed propagation and it also enhance soil fertility through organic manure from animal waste (Opiyo 2014; Kagunyu, 2014).

Rainfall pattern in Kajiado County also shows that some highland areas of Ngong and Loitokitok can support crop production. Agro-pastoralism and crop production can be encouraged in such areas. Table 5.6 shows the Water requirement for common crops in Kenya. It can be deduced from the table that highland areas of Ngong and Loitokitok with average annual rainfall of about 1000mm and seasonal rainfall of about 500mm during the long rains of March-May can support growth of crops like beans and greens, maize, sorghum and vegetable. Agro-pastoralism can therefore be a major source of livelihood in such areas. Kajiado East and Central with average annual rainfall of 600mm and 700mm can also support the growth of beans and greens even maize with little irrigation support. However, Kajiado West is an arid environment and may not be able to support rain-fed agriculture. Pastoralism will be a viable source of livelihood in such areas. This study shows that understanding temporal and spatial rainfall variation at the local level is important for decision making and adaptation planning by policy makers and rural communities in the ASALs of Kenya.

Table 5.6: Water requirement for common crops grown in Kenya

Crop	Crop water need (mm/total growing period	Total growing period (days)
Beans and greens	300-500	75-90
Cotton	700-1300	180-195
Maize	500-800	80-110
Sorghum	450-650	120-130
Soybean	450-700	135-150
Sunflower	600-1000	125-130

Source: FAO, 2010

5.8 Conclusion

Kajiado County is classified as one of the (ASALs) in Kenya which is highly susceptible to climate related events such as drought and dry spell. Findings of this study show high inter-annual and seasonal rainfall variability. This shows that rainfall is unpredictable and unreliable in the County. The result shows that sub-counties in Kajiado falls under different agro-ecological zones and are therefore impacted differently by climate related events such as drought, dry spell and floods. It is therefore important that adaptation strategies to climate change and variability in Kajiado County should be location specific to be effective. A comparison of coefficient of variation shows that there existed a spatial climate variation of about 6%, rainfall variability between seasos was wider, ranging between 2.7% and 11%. The results on standardized precipitation index (SPI) shows six years (2000, 2004, 2007, 2008, 2009 and 2011) had negative SPI between 2000 and 2011 for the long rains and seven years (2000, 2003, 2004, 2005, 2007, 2008 and 2010) had negative SPI for the short rains.

The result shows that rainfall in Kajiado County is highly influenced by altitude with areas of high altitudes like Ngong having annual rainfall that are more than twice the annual rainfall of lowlands areas of Magadi. The high variability in rainfall has also lead to increase in drought event in most areas in Kajiado County especially in low land areas of Magadi. The Results on temperature trends show an increase in minimum, maximum and average temperature in the study area between 1970 and 2013.

It is however important to note that climate variability is not only about negative impact as it also present vast opportunities for livelihood diversification, proper and effective land use and management. Arid and semi-arid lands present an opportunity for pastoralism if appropriately managed. Response to climate change and variability involves the development of effective adaptation strategies to minimize the effect and maximize the available opportunities. It also involves mitigation to reduce the amount of green house gases emitted and thereby reducing the magnitude of climate change impact in the long run. These are however founded on strong and effective policies. Policy makers should therefore come up with strong, effective and implementable policies for the management of ASALs in Kenya. The quality of policies also depends on the quality and amount of information available to the policy makers. There is therefore need to provide accurate and reliable climate and weather information for research purpose and decision makers.

The next chapter will assess the perception of Maasai pastoralist on climate change and variability in Kajiado County. The chapter presents the perception of the Maasai on rainfall and temperature trend in the study area. It also examines the indigenous knowledge of Maasai pastoralist on extreme climatic event in Kajiado County.

CHAPTER SIX

PERCEPTIONS OF MAASAI PASTORALIST ON CLIMATE CHANGE AND VARIABILITY IN KAJIADO COUNTY

6.1 Introduction

Climate change is a concern which is gaining momentum not only globally, but also in Kenya. Several studies have been done on understanding climate change and variability. Most of these studies have focused on analysis of meteorological records for determining climate trends and forecasting future climatic trends. However it has also been realized that these data based trend analysis and climate change projections are unable to capture the micro-level changes and impacts of climate change (IPCC, 2007). Rebetez (1996) stressed the difficulties in receiving and making use of scientific information in decision making process by policy makers, local communities and media personnel. It is also difficult to interpret such climatic analysis to local communities who bears the direct effects of climate change and may need to take immediate adaptation decisions.

It is important to understand the perception of rural people to climate change when planning adaptation options local level. Ban and Hawkins (2000) define perception as the process by which we receive information or stimuli from our environment and transform it into psychological awareness. It is assumed that for households to decide whether to adapt or not to climate change and variability, they must first perceive the change (Deressa *et al*., 2009; Silvestri *et al*., 2012). Studies by Amwata, (2013) and Fraser *et al*., (2011) shows that ASAL communities in Kenya are mainly dominated by pastoralist who are vulnerable to climate change and variability due to their dependence on climate sensitive livelihood activities. It is therefore important to understand the perception of ASAL communities to climate parameters and relate their perception with meteorological data. Studies on perception, awareness and local knowledge at the household and community levels can provide the basis for concepts and methods for assessing climate change vulnerability and adaptation strategies for pastoral livelihoods. Planning adaptation strategies for climate change requires adequate understanding of climate parameters by all stakeholders including researchers, pastoralist communities, policy makers, extension agents and the private sector.

This chapter therefore presents the perception of Maasai pastoralist on climate change and variability, and analysis of perceived risk of changing climatic parameters on the pastoralist livelihoods. The chapter also provides information on indigenous knowledge used by the Maasai to predict climate parameters. These findings will be useful for the government and policy makers for climate change adaptation planning in Kajiado County.

6.2 Results

6.2.1 Perception of Maasai pastoralists on rainfall trends in Kajiado County

Local knowledge of rainfall variability is based on long term experience and familiarity with seasonal rainfall pattern in an area. Pastoralists living in arid and semi-arid lands of Kenya are particularly vulnerable to climate induced stress due to over dependence on climate sensitive livelihood activities. Understanding their perception to rainfall pattern is therefore very important in addressing adaptation to extreme climatic events especially drought. The perception of the Maasai pastoralists on rainfall trends in the last 30 years presented in Figure 6.1 shows that 83% of the respondents perceived that rainfall is reducing in the study area, 12% perceived that rainfall is unpredictable and 5% reported that they don't know if rainfall is changing in the study area in the last 30years. Focus group discussion participant also agreed that rainfall is reducing and there is an increase in drought and dry spell occurrence in the County. They agreed with one of them who said that:

"Although Maasai are known worldwide as pastoralists, however, the rate at which drought and dry spell is increasing and also the continuous sales and fencing of land will most likely lead to the end of pastoralism in Kajiado County within the next 20years."

Previous studies by Kabubo-Mariara (2008); Silvestri *et al*., (2012) and Bryan *et al*., (2013) conducted in ASALs of Kenya reported that rural household generally perceived a reduction in rainfall amount over the years. Result of this study also agrees with Opiyo (2014) who reported that 72.3% of household interviewed in Turkana County of Kenya perceived that the length of rainfall season have decreased over the last 30 years. Amwata (2013) also reported that agro-pastoralists in similar ecosystem perceived a decrease in the amount of rainfall.

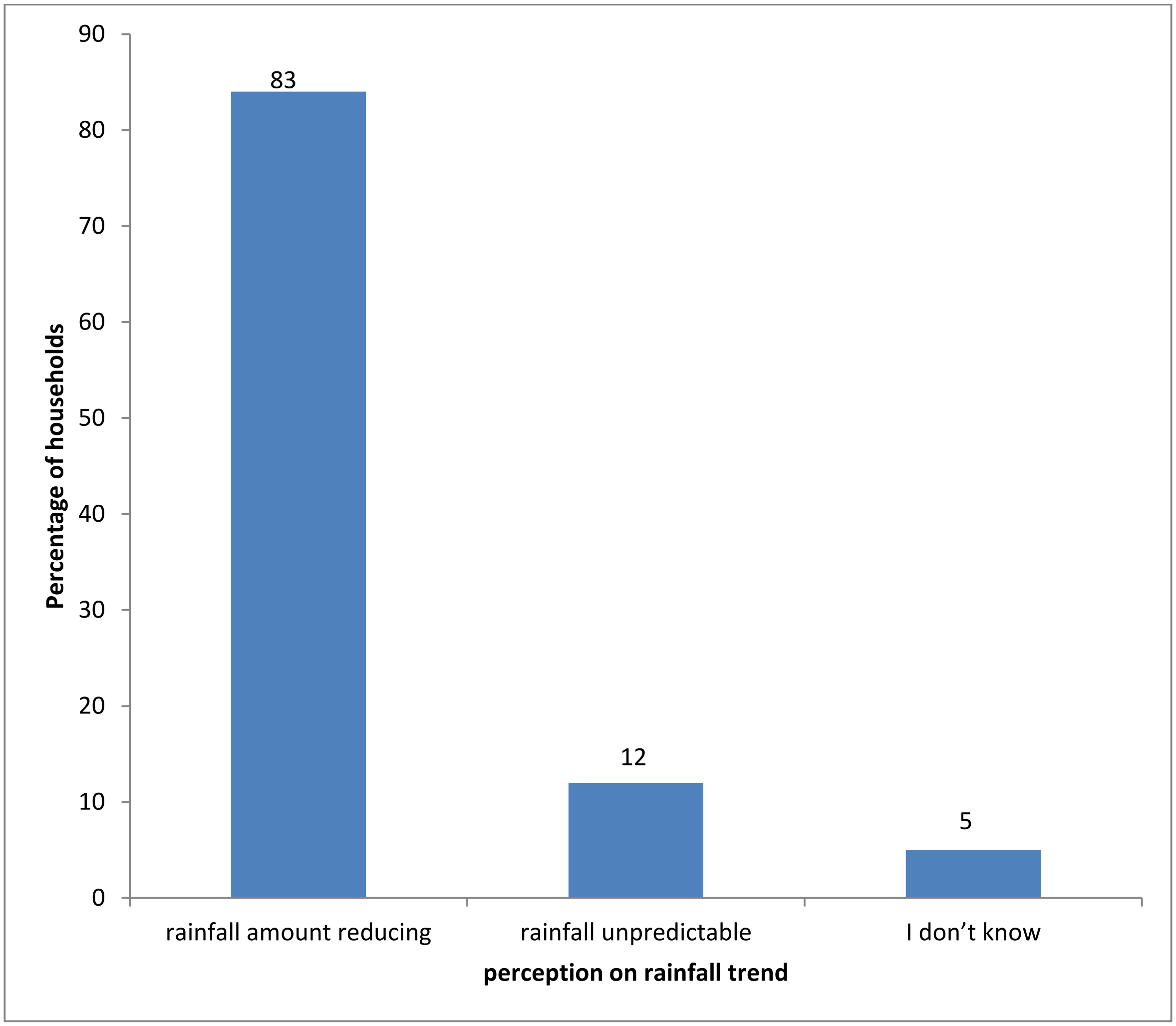

Figure 6.1: Perception of the Maasai community on annual rainfall trend in Kajiado East in the last 30years

6.2.2 Perceptions on extreme climatic occurrence in Kajiado County

The perception of Masaai pastoralist on years of extreme climatic occurrence shows that drought and dry spell is the major climatic challenge faced by pastoralist in Kajiado County. The results in table 6.1 revealed that the Maasai observed extreme drought in ten (10) years (2014, 2011, 2009, 2005, 2000, 1994-1996, 1990-1991, 1984, 1981-1980, 1976) from 1976 and 2013. The result showed that drought occurrence is increasing in

Kajiado County in recent years. This concurs with the findings of Opiyo (2014) who reported that drought occurrence has changed from every 8-10 years to every 2-3 years in ASALs of Kenya.

Amwata (2014) also reported similar years of drought in a study conducted in the ASALs of Southern Kenya. The Findings of this study also corroborate previous observations by Hastenrath *et al*., (2011); Cook and Vizy (2013); Omondi *et al*., (2013) conducted in arid and semi-arid lands in eastern Africa. The result also shows heavy rainfall occurred in Kajiado in 1988 and 1997 causing bumper harvest of crops and also flood in the study area. This agrees with several studies (Serigne and Verchot, 2006; SEI, 2009 and Amwata 2013) which reported occurrence of *El Nino* rains in 1988, 1997-1998 and 2008 which caused floods in most parts of Kenya. This finding shows the importance of indigenous knowledge in climate observation. It shows that the Maasai communities keep adequate mental records of extreme climatic events and they have names for years of extreme drought for easy remembrance. It can be deduced that rural dwellers especially farmers and pastoralists who depends on rainfall for their livelihood sustenance have useful information on climatic trends and they should be actively involved in decision making in their communities.

Table 6.1: Perceptions of the Maasai pastoralist on extreme climate events in Kajiado East sub-County

Year	Events	Local name of drought	Impact on people
2014	Drought		Death of livestock and starvation
2011	Drought		Loss of animals and migration of animals to national park Ambroseli and Loitokitok
2009	Drought		Death of livestock and wild animals. People moved their livestock as far as Tanzania
2005	Drought and famine	*emperi*	Death of livestock and wildlife. Lack of grains for human
2000	Drought		Maasai were given yellow maize for food aid. Loss of animals
1997	Heavy rains (El Niño)		Bumper harvest of maize. Livestock suffered from bloat
1994-1996	Drought	*emperi*	Livestock taken to Nairobi in search of pasture for the first time
1990-1991	Drought		Not enough grazing for livestock, Maasai women started diversifying sources of income in bead making
1988	Heavy rains		Sufficient pasture for animals and flood
1984	Drought	*Engunememasi Kiroi*	East Coast fever (*Oldikana*) outbreak. Maasai were given yellow maize for the first time as food aid. The drought was called the drought of the yellow maize
1980 - 1981	Drought		People starved and livestock died
1976	Drought	*Oloik*	Starvation and death of animals

Source: Focus group discussion

6.2.3 Perception of the Maasai on the level of risk of drought in Kajiado County

The perception of the Maasai pastoralists on the level of risk to drought Figure 6.2 shows that 81.4% of the respondent agrees that drought is causing high risk to the pastoral economy in the study area, 16.4% perceive that drought is causing medium risk, while 2.2% perceive that drought is causing low risk in the study area. Several studies (Nkedianye *et al*., 2011; Nicholson 2014; Opiyo 2014) have reported the effect of increasing drought occurrence on the pastoral economy in the ASALs of Kenya. Drought poses serious challenges to the pastoral economy which account for 90 percent of employment opportunities and 95 percent of family incomes and livelihood security in ASALs of Kenya (ASAL Policy, 2012). According to Intergovernmental Panel on Climate Change (IPCC 2014) report, there is likely to be a marked increase in drought severity over much of Eastern Africa by 2050, this will threaten climate sensitive economy like agriculture and pastoralism in the region. This result confirms the high risk of drought in the ASALs of Kenya and further buttress the need for collaboration among stakeholders (government, researcher and the community) to develop coping and adaptation strategies to address climate change and its effect in the ASALs of Kenya.

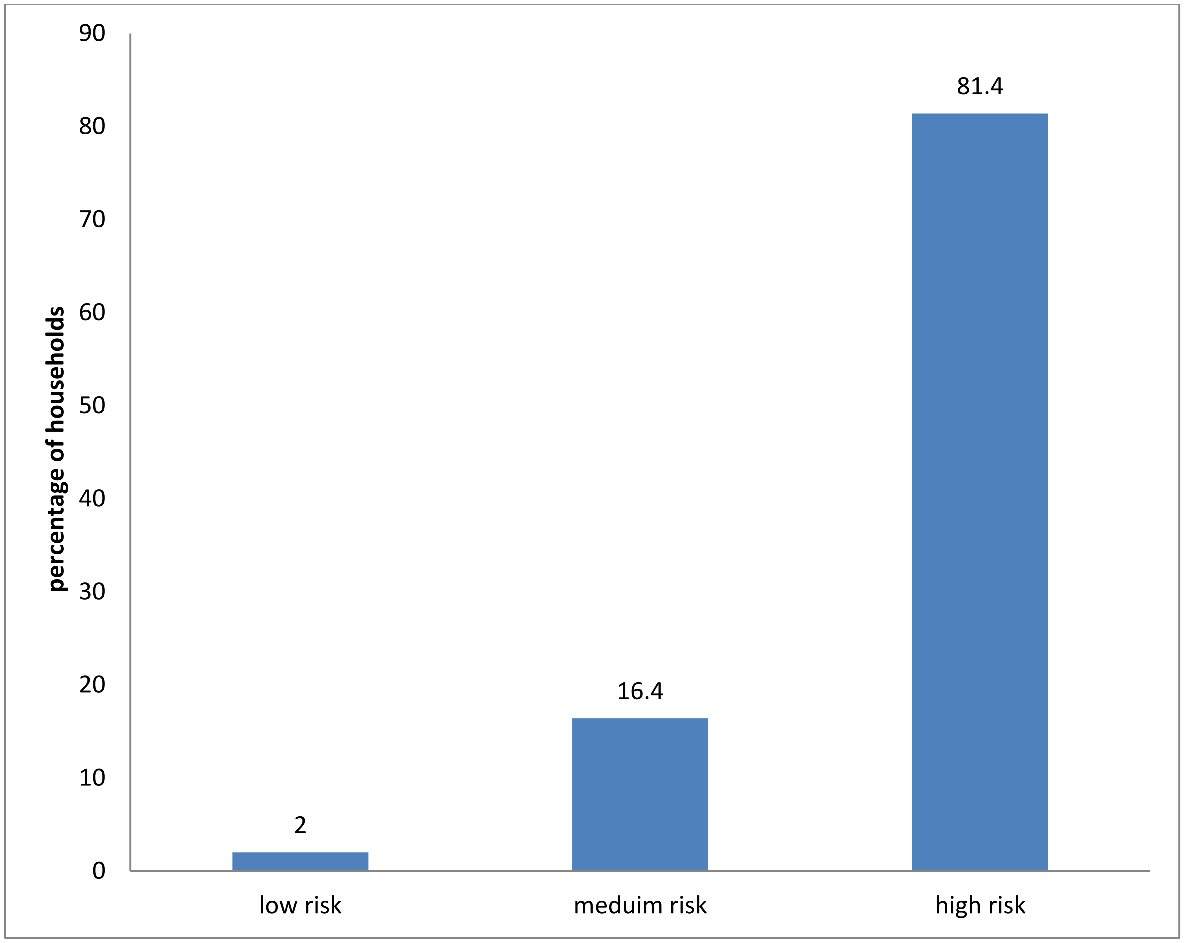

Figure 6.2 Maasai pastoralist perception on the level of risk of drought in Kajiado County

6.2.4 Perception of Maasai pastoralists on temperature change in Kajiado County

The result on the perception of Maasai pastoralist on temperature change in the study area (Figure 6.3) showed that 81% of the respondent perceived that average temperature is increasing, 6% perceived that temperature is unpredictable while only 4% perceived that temperature is reducing. This shows that the Maasai pastoralists are already experiencing the effect of increasing temperature on their livelihoods. Global climate model for East Africa indicate that climate change may increase temperature by 4^0C by the year 2100 (IPCC, 2007). Increased temperature has been known to have significant impact on water availability and pasture resources, thus likely to aggravate vulnerability of pastoralists (Opiyo, 2014). This study agrees with the findings of Omolo (2010), who reported that farmers in arid and semi-arid lands of Kenya already perceive the effect of change in temperature and rainfall, and that they are developing coping strategies to the adverse effect of climate change.

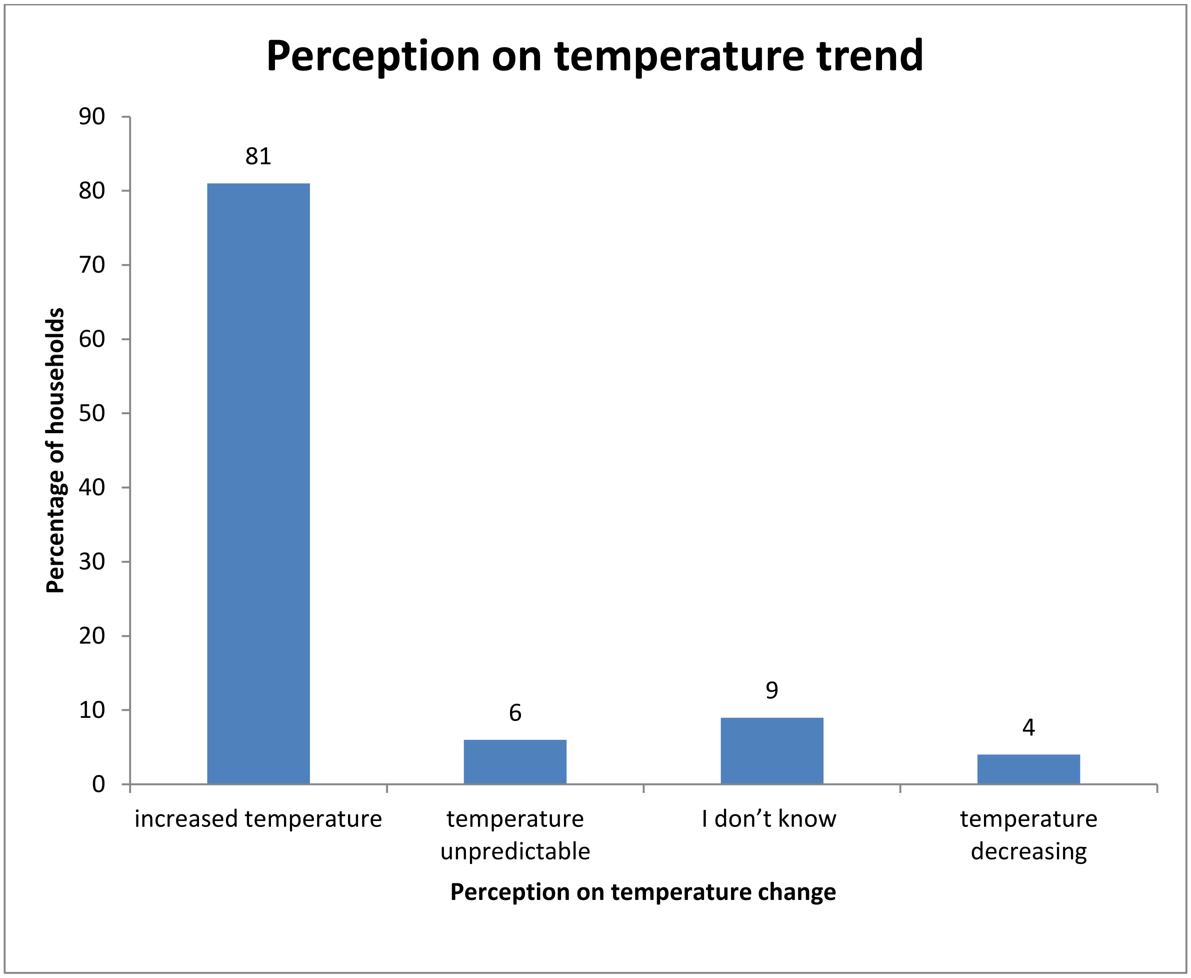

Figure 6.3: Perception of Maasai pastoralist on temperature trends in Kajiado County in the last 30 years

6.2.5 Co-relating meteorological observed climate trends and perceived climate trends in Kajiado County

Understanding perceptions of communities on climate change and relating it to meteorological evidence is important in planning adaptation strategies with rural communities. Comparing perceptions of Maasai pastoralists on rainfall change with meteorological rainfall trend analyzed in chapter four of this study shows that perception on annual rainfall trend does not agree with meteorological rainfall trend for the study area. While pastoralists perceived a decrease in rainfall amount, meteorological data reveals that there is no significant difference in rainfall trend in the last 30 years. Meteorological data however reported high coefficient of variation in rainfall amount which means that the rains are erratic and unpredictable in the study area. The high variation in rainfall pattern would have led to shift in seasons and reduction in rain days, and this may be what the Maasai pastoralist are observing as decrease in rainfall amount. Opiyo (2014) in a study conducted in similar ecosystem also reported no significant difference in annual rainfall trend in ASALs of Kenya; he however confirms high level variation in rainfall pattern in ASALs of Kenya. Perception of Maasai pastoralist on drought occurrence in the study area agrees with meteorological data. From the focus group discussions, majority reported increase in frequency of drought occurrence in recent years and this agrees with meteorological findings as shown in the number of years with negative SPI since the year 2000. Several studies by Orindi *et al*., (2007); ICPAC (2007) and Amwata (2013) also confirmed increase in frequency of drought in Kajiado County.

As indicated by temperature trend analysis, Maasai pastoralists perceived that temperature has been increasing in Kajiado County in the last 30years. This shows that the impact of global warming is already being felt by people living in the rural areas. Studies by Opiyo (2014); Amwata (2013) and King'uyu *et al*., (2000) conducted in similar ecosystems have also reported significant increase in temperature in arid and semi-arid regions of Kenya.

6.3 Traditional rain forecasting among Maasai pastoralists

Communities have over the decades used various signs to predict the onset of rainfall. According to Amwata (2013), rural communities in Kenya forecast rain using traditional indicators such as wind, moon, stars, birds, insect, animals, plant clouds and lightning patterns. The ability of Luo communities of former Nyanza province to predict rainfall was also reported by Ogallo (2004). He noted that these communities use plant phenological stages, position and direction of wind, movement of rain cloud and frequency of a westerly driven swarm of insect as indicators to predict onset of rainfall.

Various signs have also been used by Maasai communities in Kajiado to forecast rainfall. The phenological stage of plants (Table 6.2) is one of the most commonly used signs by Maasai communities to forecast rainfall. The Maasai communities also use their closeness to wild animals to predict rainfall. They observe migratory pattern of some animals to forecast onset of rainfall. They also use sounds from animals such as Lion and Ostrich to predict rainfall. Other indicators used by Maasai pastoralist to forecast rains are:

(1) Movement of safari ants: The Maasai especially the women use the direction of movement of safari ants to predict rain

(2) Animal intestine: The Maasai elders can use the shape and colour of the intestine of a slaughtered cow or goat to predict rain or drought for that season. If the colour of the intestine is black, it means there will be drought

(3) High temperature: intense heat especially in the night is a sign that the rainy season will start in a few days

(4) Pattern of stars in the night and the shape of the moon: The Maasai elders also use pattern of stars and the shape of the moon to predict onset of the raining season

(5) Restlessness of animals: The Maasai use restlessness of animals such as giraffes and Zebras to forecast rainfall.

Table 6.2: Plants indicators used to forecast rain in the study area

Plant name	Plant or tree phenological stages and rainfall prediction
Acacaia tortilis	Blooming without flowers (Long rain within a week)
Nagal atumia	Appearance of fruit (Short rains will fall within two weeks)
Commiphora	Full bloom (Short or long rain will fall within two weeks)
Ficus sycomorus	Full bloom (Short or long rain will fall within two weeks)
Melia volkensii	Blooming with flowers (Short rains within one week)
Boophone disticha	Pink flower falls (Short rains within one week)
Ficus Thonningii	Full bloom (Short rains would fall within ten days)
Ficus vasta	Full bloom (Rain falls within two weeks)
Kititiu	Blooms and flower bud appears (Rain will fall within ten days)
Orng'arooji	Shed leave (Rain will fall within two weeks)

Source: Field study

6.4 Conclusions

Response to climate change and variability involves the development of effective adaptation strategies to minimize the effect and maximize the available opportunities. Rural communities over the years have developed indigenous methods of predicting climate trends. They also have useful information about climatic trends and occurrence of extreme climatic events such as drought in their communities. It is therefore important to understand the perception of communities about climate change and variability in planning adaptation strategies. This chapter shows that Maasai communities perceived that the rains are reducing in the study area; they also perceived increase in frequency of drought in recent years. The study shows that the perception of Maasai pastoralist on temperature change agrees with meteorological evidence provided in chapter five of this study. This shows that Maasai pastoralists have a good understanding of weather pattern in the study area and climate change is already being perceived by pastoralist in Kajiado County. This study recommends that both indigenous and scientific knowledge should be combined in understanding and presenting climatic information to the communities. The communities are very important stakeholders in adaptation planning and understanding their perception about climate change and variability is important in climate adaptation planning. The findings of this study will therefore be useful for researchers and policy makers in planning adaptation strategies in ASALs of Kenya.

The next chapter will examine household vulnerability to climate change and variability within Kajiado East sub-County. The chapter calculated vulnerability index for household using vulnerability indicators. Vulnerability maps showing the level of vulnerability of households and communities were also produced in the next chapter.

CHAPTER SEVEN
ASSESSING HOUSEHOLD VULNERABILITY OF MAASAI PASTORALIST COMMUNITIES TO CLIMATE CHANGE AND VARIABILITY

7.1 Introduction

Vulnerability is a concept used widely in various fields of specialization and it has different definition based on the field of study and the context of use (Fussel, 2007). Many studies have been conducted on vulnerability to climate change and its extremes and different researchers have defined vulnerability according to their own perception.

The concept and definition of vulnerability that has been used by different studies revolves around the explanation of lack of adaptive capacity in both social and natural system. Climate change vulnerability has been studied by different scholars as a composite of adaptive capacity, sensitivity and exposure to hazard (Adger and Kelly 1999; Paavola 2008; Yuga *et al*., 2010; Deressa, 2010; Acheampong *et al*., 2014). Adaptive capacity can be defined as the ability to withstand or adjust to the changing context; it is the ability to implement adaptation measures that help avert potential impacts of climate change and variability (Opiyo, 2014; Acheampong *et al*., 2014). Sensitivity is defined as the ability of a system to be affected by climate change and its extremes; it describes conditions that can trigger an impact or ameliorate hazard. Exposure is the nature and change in climate variables and extreme events; it is the physical impact of climate change such as change in rainfall pattern or rise in temperature range (Kasperson *et al*., 1995; Paavola 2008; Opiyo, 2014).

Climate change vulnerability can be analyzed from global level (IPCC 2014; Brooks 2004) to regional level (Deressa *et al*., 2009; Acheampong *et al*., 2014) and household level (Opiyo, 2014). The choice of vulnerability analysis scale depends on the aim of the research, available data and the methodology of the study. Most of the available scientific literatures on climate vulnerability analysis focus on national and regional vulnerability assessment usually for national or regional adaptation planning (Opiyo *et al*., 2014; Hinkel 2011). While vulnerability analysis at the national level is necessary for policy formulation and national planning; household vulnerability assessment conceptualizes how climate change and variability impacts directly on the household members and measures their ability to adapt. This is particularly useful for resource allocation and planning for adaptation strategies at the local level. Pearson *et al*., (2008) and Sherwood (2013) reported that vulnerability indices are diverse for the different multiple spatial scales and that household vulnerability assessment can be used to demonstrate how climate change affects livelihood of different communities. The aim of this chapter is to assess vulnerability of Maasai pastoralists' communities to climate change and to develop vulnerability maps for communities and households in Kajiado east sub-county. Vulnerability was assessed in this study by calculating vulnerability index for pastoralist households in the study area. The vulnerability index was calculated using vulnerability indicators that were selected by the Maasai communities and the researcher. The result of this study will assist policy makers in resource allocation and climate adaptation planning in the arid and semi-arid lands of Kenya.

7.2 Vulnerability indicators and expected direction with respect to vulnerability

The vulnerability indicators used for this study is presented in Table 7.1. These vulnerability indicators were categorized according to the definition of vulnerability as a function of adaptive capacity, exposure and sensitivity. The Maasai communities and the researcher also analyzed the expected impact the selected indicators will have on vulnerability in the study area, identifying indicators that should enhance vulnerability and those that should reduce vulnerability.

In this study, the adaptive capacity is represented by wealth, infrastructure, access to information and literacy level. Wealth enhances the ability of communities to cope and recover from climate extremes. Size of herds, size of land owned and mobility of livestock are indicators used by Maasai pastoralist to access the level of wealth of pastoralist households. The availability of basic infrastructures plays an important role in adaptation to climate change. It increases the ability of rural dwellers to diversify their sources of income thereby enhancing their adaptive capacity. Likewise, availability of hospitals can enhance the provision of preventive treatments for diseases associated with climate change such as malaria and meningitis. O' Brien *et al*. (2004) reported that areas with better infrastructure are more likely to have a higher capacity to adapt to climate variability and change.

In this study, sensitivity is represented by level of education, household size, gender and age of household head. It is believed that the level of education of the household head impact on the sensitivity of the household to climate variability and change. Educated household head will be able to understand, interpret and act on information and available opportunities. It has also been reported that households with smaller size are more likely to withstand climate change and its extreme (Opiyo, 2014). Exposure in this study is represented by the frequency of extreme climatic events such as droughts and floods and also by change in temperature and amount of precipitation.

Table 7.1: Vulnerability indicators and expected direction with respect to vulnerability

Determinants of Vulnerability	Vulnerability indicators	Description of indicator used for analysis	Relationship between indicator and vulnerability
Adaptive capacity	Wealth	Herd size, livestock diversity, land size, non-farm income, income from crop farming	The more the size of land own and income generated by households the less the vulnerability to climate change
	Access to information	Visit by extension agents, access to climate information	The more access the household has to climate information the less their vulnerability
	Infrastructures and asset	Access to electricity, toilet and hospitals. Own radio and TV	The more the households that have access to electricity, hospitals and other asset the less their vulnerability
Sensitivity	Household characteristics	Household size, number of dependent, marital status, gender of household head, age of household head	The higher household size and number of dependents, the higher the vulnerability. Female headed households are more vulnerable
	Literacy level	Level of education	The higher the literacy rate, the less the vulnerability
Exposure	Extreme climates	Frequency of drought and floods	The higher the frequency of extreme events the more the vulnerability
	Change in climate	Temperature change Precipitation change	Reduced rainfall and increase temperature increase vulnerability

7.3 Demographic characteristics of respondents in each ward

The demographic characteristics of each administrative ward in Kajiado east is presented in Table 7.2. Average age of household head ranges from 53years in Imaroro to 56.8 years in Kenyawa-Poka. The table shows that the wards has similar average household size with Kitengela having the highest household size of 8, followed by Imaroro 8, Kaputei North has 7 members, Kenyawa-Poka has 7 and Sholinke has the least with 7 members. Amwata (2013) reported an average household size of 5 members in a study conducted in Kajiado County. Kenyawa-Poka ward had the highest average land size of 180.3Ha; Imaroro had an average land size of 127.4Ha; Sholinke had an average of 88.5Ha; Kaputei North 84.5Ha and Kitengela had the least average land size of 60.3Ha. This concur with the findings of Amwata (2013) and ROK (2013) that land subdivision and increased sales of land around Kitengela have reduced land available for pastoralism and agro-pastoralism. ROK (2013) also reported that Kenyawa-Poka has the largest land size of 1,340.4sq.km, followed by Imaroro 790.90sq.km and least for Kaputei North 88.70sq.km.

Table 7.2: Demographic characteristics of respondent in each ward

Ward	Average Age of HH (years)	Average Household size	Average Land owned (Ha)
Kaputie North	55.9	7	84.5
Kitengela	55.5	8	60.3
Sholinke	53.8	8	88.5
Kenyawa-poka	56.8	9	180.3
Imaroro	53	7	127.4

HH – Household head

The result of the level of education of Maasai household heads in each ward (Table 7.3) showed that Kaputie North (44.4%) has the highest percentage of Maasai pastoralist with no formal education, followed by Kenyewa-Poka (40%), Kitengela has 35%, Sholinke has 31.2% of respondent with no formal education and 15% of the respondent in Imaroro had no formal education. The result also showed that only Kitengela ward and Imaroro ward had respondents with Diploma and University levels of education. Kitengela ward had 10% and 5% of the respondents having Diploma and University education; while Imaroro had 5% and 5% of the respondents having Diploma and University education.

Table 7.3: Level of education of respondent in each ward

	Level of education (%)					
Ward	No formal	Primary	Secondary	Diploma	University	Others
Kaputie North	44.4	50	5.6	0	0	0
Kitengela	35	35	10	10	5	5
Sholinke	31.2	37.5	31.2	0	0	0
Kenyawa-poka	40	55	5	0	0	0
Imaroro	15	60	15	5	5	0

7.4 Analysis of vulnerability of the pastoral households to climate change in Kajiado County

The social, economic and environmental variables affecting vulnerability are summarized in Table 7.4. Result shows that only 8.5% of the households were headed by females and these confirms the findings of Omolo (2010) that Maasai communities are patriarchal and women are less involved in decision making, and are often relegated to taking care of the children and other household activities. This is expected to reduce the female headed household early access to climatic information and early warning information and affect their ability to respond early to extreme climatic events. Data on household size shows that 91.5% of respondents had household size of more than Five (5) people. Results showed that 33% of the household heads had no formal education and level of education affect the ability of pastoralist to adapt to climate change. Lack of formal education affects the ability of the household to understand and interpret climate information for decision making (Opiyo *et al*., 2014). Various findings (Yohe and Tol 2002; Skjeflo

2013; Opiyo 2014) has shown that household size has a significant influence on the vulnerability of the households to climate change and climate extremes.

Smaller household are usually less susceptible to climate extreme events such as drought. This is because food scarcity is one of the main challenges during drought and the lesses the household size, the easier it is to cope with scarcity of food. The results also showed that other social and economic variables such as marital status, access to extension agents, herd size, livestock diversity and access to credit facilities positively influenced vulnerability in the study area. This result concur with the findings of Katoka *et al*., (2011) and Opiyo *et al*., (2014) which similarly reported that most of these variables affects household vulnerability to climate change in the pastoralist communities. The influence of variables on the vulnerability of Maasai pastoralists (table 7.4) was determined together with the Maasai communities. The researcher with the agreement of the communities assigned a positive sign when the variable is agreed to increase vulnerability in the study area and negative sign when it reduces vulnerability. The Maasai community generally agreed that to a large proportion, the result of this study gives a reflection of their experience on climate change and extreme climatic events and the vulnerability indicators used actually influence their vulnerability to climate change.

Table 7.4: Social, economic and environmental factors and their effects on vulnerability

Hypothesized variables	Percentage of household	Influence on vulnerability
Social variables		
Gender of HH head: female headed households	8.5	+
Age of HH head: 50+ years	64.9	+
Experience in the area: 45+ years	56.4	-
HH size: 5+ persons	91.5	+
Education level: no primary education	33.0	+
Dependents: 5+ persons	9.6	-
Marital status: single (including divorced and widowed)	10.6	+
Visit by extension officers: no access to extension services	83.0	+
Receive climate information	90.0	-
Economic variables		
Crop-farming income: with income from crop farming	7.4	-
Non-farm income: with income from non-farm activities	74.5	-
Herd size: 100+ total herd size	85.1	-
Livestock diversity: own 2+ domestic animal types	93.4	-
Land size: own 100+ acres	57.4	-
HH members employed: 3+ members employed	36.2	-
Credit access: have no access to credit	72.3	+
Livestock mobility: able to move livestock freely	62.8	-
Own radio	94%	-
Own TV	68%	-
Access to electricity	22%	-
Access to hospital	94%	-
Access to toilet	72%	-
Environmental variables		
Temperature: noticed increase	93.6	+
Rainfall: noticed decrease	90.0	+
Drought: experience drought within the last 10 years	100.0	+
Floods: experience floods within last the 10 years	74.5	+
Drought frequency: every year	47.9	+
Floods frequency: every year	2.1	-

Positive sign means variables increase vulnerability while negative sign means they reduce vulnerability. HH - household

Table 7.5 shows the result of the factor score for the first principal component analysis and its association with the vulnerability variables. Principal Component Analysis was run on the indicators listed in Table 7.4 to generate the factor scores. The first principal component was used to generate the factor scores (weight) because it explains 91% of the variations. Vulnerability index was computed based on the definition of vulnerability as a net effect of adaptive capacity minus exposure and sensitivity. The indicators of adaptive capacity which were positively associated with the first principal component analysis and the indicator of sensitivity and exposure which were negativly associated with the first principal component analysis were used to calculate the vulnerability index. This is because the vulnerability equations shows that increase in adaptive capacity contributes to reduction in vulnerability, while increase in exposure and sensitivity increases vulnerability. The variables with higher factor scores have higher influence on vulnerability in the study area. Vulnerability index were calculated for each of the 305 households studied. The households were categorized into less vulnerable, moderate vulnerable and vulnerable based on their vulnerability index.

Table 7.5: Factor scores for the first principal component analysis

Factors **Social vulnerability variables**	**Factor Scores**
Gender HH head	0.02
Age of HH head: 50+ years	-0.0138
Experience in the area: 45+ years	0.0158
HH size: 5+ persons	-0.051
Education level: no primary education	-0.13
Visit by extension workers: no access to extension services	-0.01
Receive climate information	0.001
Dependents: 5+ persons	-0.06
Marital status of HH head: single (including divorced and widowed)	0.04
Own radio	0.0000
Own television	0.4
Own mobile phone	0.3
Access to electricity	0.2
Toilet	0.19
Access to a hospital	0.003
Economic vulnerability variables	
Crop farming income: with income from crop farming	0.19
Non-farm income: with income from non-farming activities	0.04
Herd size: 100+ total herd size	0.286
Livestock diversity: own 2+ domestic animal types	0.22
HH members employed: 3+ members employed	0.030
Credit access: have no credit access	0.002
Livestock mobility: able to move livestock freely	0.15
Land size: own 100+ acres	0.90
Environmental vulnerability variables	
Rainfall: noticed decrease	-0.02
Temperature: noticed increase	-0.12
Drought: experienced drought within the last 10 years	-0.22
Floods: experienced floods within the last 10 years	0.0001
Drought frequency: every year	-0.11
Floods frequency: every year	0.0004

7.5 Vulnerability level of administrative wards in Kajiado east sub-County

Presenting results of climate vulnerability studies in simple understandable format such as tables, maps and charts makes it easier for all stakeholders especially policy and decision makers to understand and take necessary adaptation measures against climate change and variability.

This study calculated vulnerability index for 305 households in 56 Maasai communities in the five administrative wards in Kajiado east sub-County (ANNEX 3). These communities were categorized into highly vulnerable, moderately vulnerable and less vulnerable communities in the sub county. The percentage of households in the vulnerable categories in the five wards in Kajiado East is presented in table 7.6. The households were classified into three categories using the vulnerability index. (1) Highly vulnerable household are households that cannot cope with climatic stress and needs urgent intervention, they are households that are critically affected by climate change and variability. (2) Moderately vulnerable are those that will need immediate assistance in times of extreme climatic events but they are not as vulnerable as the first group. (3) Less vulnerable groups are those that can still cope with the effects of climate change and variability.

Table 7.6 Percentage of households in each vulnerability categories by wards

	Vulnerability Levels of households		
Ward	**High**	**Moderate**	**Less**
Imaroro	15.0%	75.0%	10.0%
Kaputiei North	33.3%	38.9%	27.8%
Kenyawa-Poka	5.0%	75.0%	20.0%
Kitengela	15.0%	50.0%	35.0%
Oloosirkon/Sholinke	18.8%	81.3%	0.0%
Average	**17.0%**	**63.8%**	**19.1%**

The result shows that in all the wards, most of the households fall within the moderately vulnerable category. Kaputiei North has the highest number of highly vulnerable household (33.3%), followed by Oloosirkon/Sholinke with 18.8%, Kitengela and Imororo has 15% each and it was least for Kenyawa-Poka with 5%. Oloosirkon/Sholinke has the highest number of households in the moderately vulnerable category 81.3%, followed by Imaroro and Kenyawa-Poka with 75% each; Kitengela has 50% while Kaputiei North has 38.9% of his households in the moderately vulnerable category. Kitengela has 35% of his households in the less vulnerable category, followed by Kaputiei North 27.8%, Kenyawa-Poka 20%, Imaraoro has 10% of its household in the less vulnerable category and no household in Oloosikon/Shilinke fell within the less vulnerable group.

The result shows high disparity in the vulnerability of household within the same ward. It concur with the findings of Orindi *et al*., (2007) which reported that land sub division and sales among the Maasai in Kajiado has increased the standard of living of few Maasai while most are left highly vulnerable and unable to practices their pastoralist system. Increase in dry spell and drought over the last few decades coupled with restriction in animal movement have also increased vulnerability of Maasai pastoralist to climate change and variability (Kakota *et al*., 2011; Opiyo *et al*., 2014).

7.6 Vulnerability maps of households and communities in Kajiado East sub County

Maps have the advantage of presenting data in an easily assessable, readily visible and eye catching manner. Mapping vulnerabilities to climate change is a key planning tool for government and policy makers in allocation of resources and adaptation planning. There is the urgent need in Kenya for availability of information especially at the local levels where intervention are needed for establishing early warning systems, disaster risk response and capacity building.

Figure 7.1 shows the vulnerability map of households in Kajiado east sub-County. The map shows that households in most communities in Kajiado east are moderately vulnerable to climate change and variability. The map also revealed a high level of variation in the vulnerability of some households within the same community. This shows that although communities are exposed to the same climatic factors, the adaptive capacity which differs from household to the other has a significant effect on household’s vulnerability. Fussel (2007) and Deressa (2010) reported that individual households within the community vary in socio-economic characteristics such as level of education, weaith, access to credit and political power; which are responsible for variation in vulnerability levels.

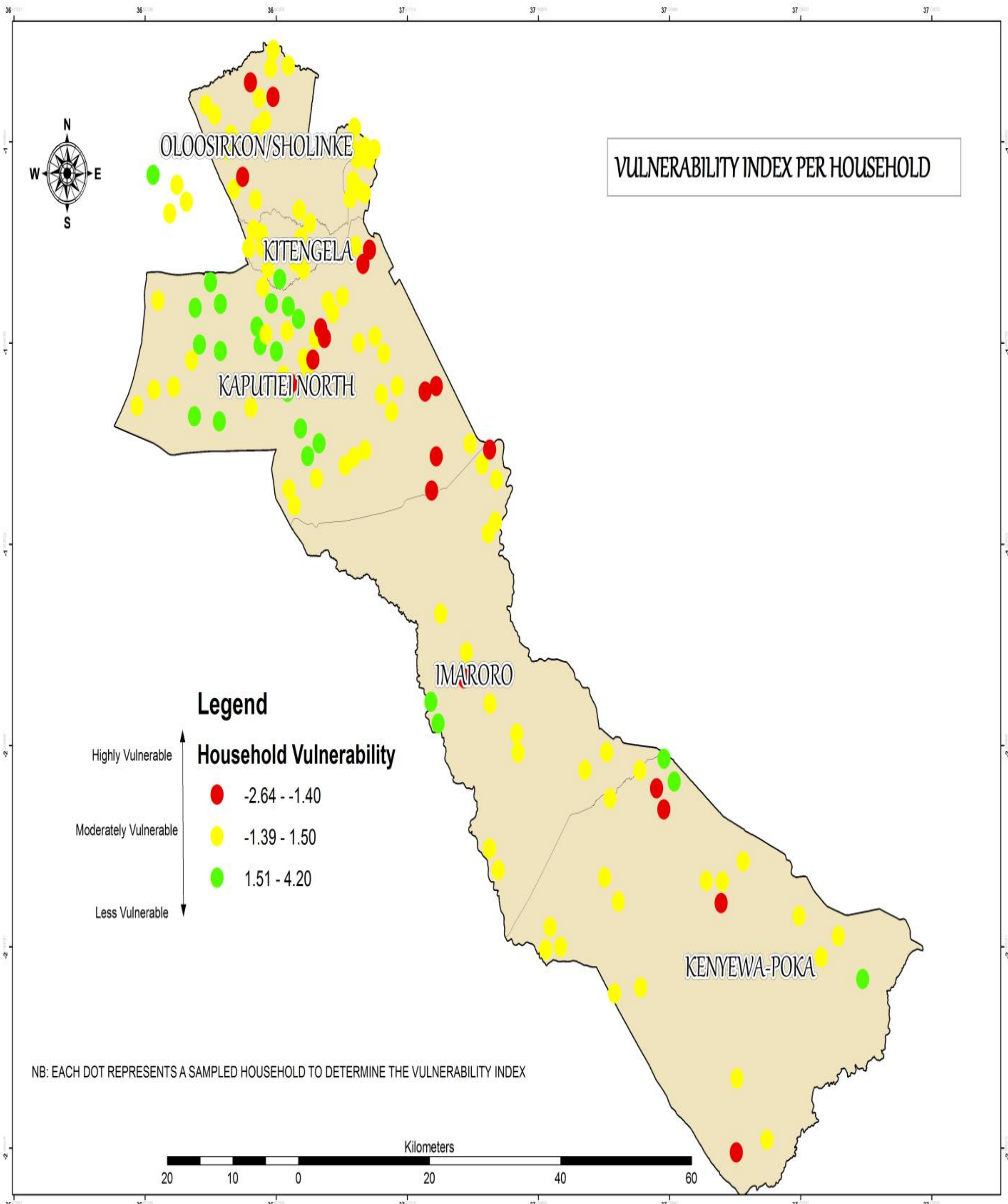

Figure 7.1: Map showing the level of vulnerability of households to climate change and variability in Kajiado East

Mapping household vulnerability is important in identifying vulnerable household within a community and also understanding vulnerability pattern of household in the community. However, mapping vulnerability at the community level provides information for policy makers and decision makers to take informed decisions that will enhance resilience of vulnerable communities. It allows site specific targeting of intervensions that is cognizant of the variability in space and time.

Figure 7.2 shows the vulnerability map of communities in Kajiado east. The map categorized communities into highly vulnerable, moderately vulnerable and vulnerable communities based on their vulnerability index. The map revealed that although most communities in Kaputie North ward are moderately vulnerable; Maasai communities in Iloposat, Lenihani, Oloshaiki and Olturoto are highly vulnerable to climate change and variation. Kitengela ward has the highest number of Maasai communities that are less vulnerable; this might be due to the availability of basic amenities such as good roads, electricity and hospitals. It has been reported that availability of basic amenities such as good roads, schools and hospitals enhance the adaptive capacity of communities and therefore reduces vulnerability of communities to climate change (Deressa, 2010; Acheampong *et al*., 2014). Maasai communities that are highly vulnerable to climate change and variability in Sholinke ward are communities living in Oloosirikon and Korrompoi. The other Maasai communities in Sholinke are moderately vulnerable to climate change and variability. The map shows that communities in Mbilin and Koonza of Imaroro ward are also highly vulnerable to climate change and variability. In Kenyawa-Poka ward, most communities are moderately vulnerable to climate change and variability, however, the map shows that communities in Noompai are highly vulnerable while those in Esilanke are less vulnerable to climate change and variability.

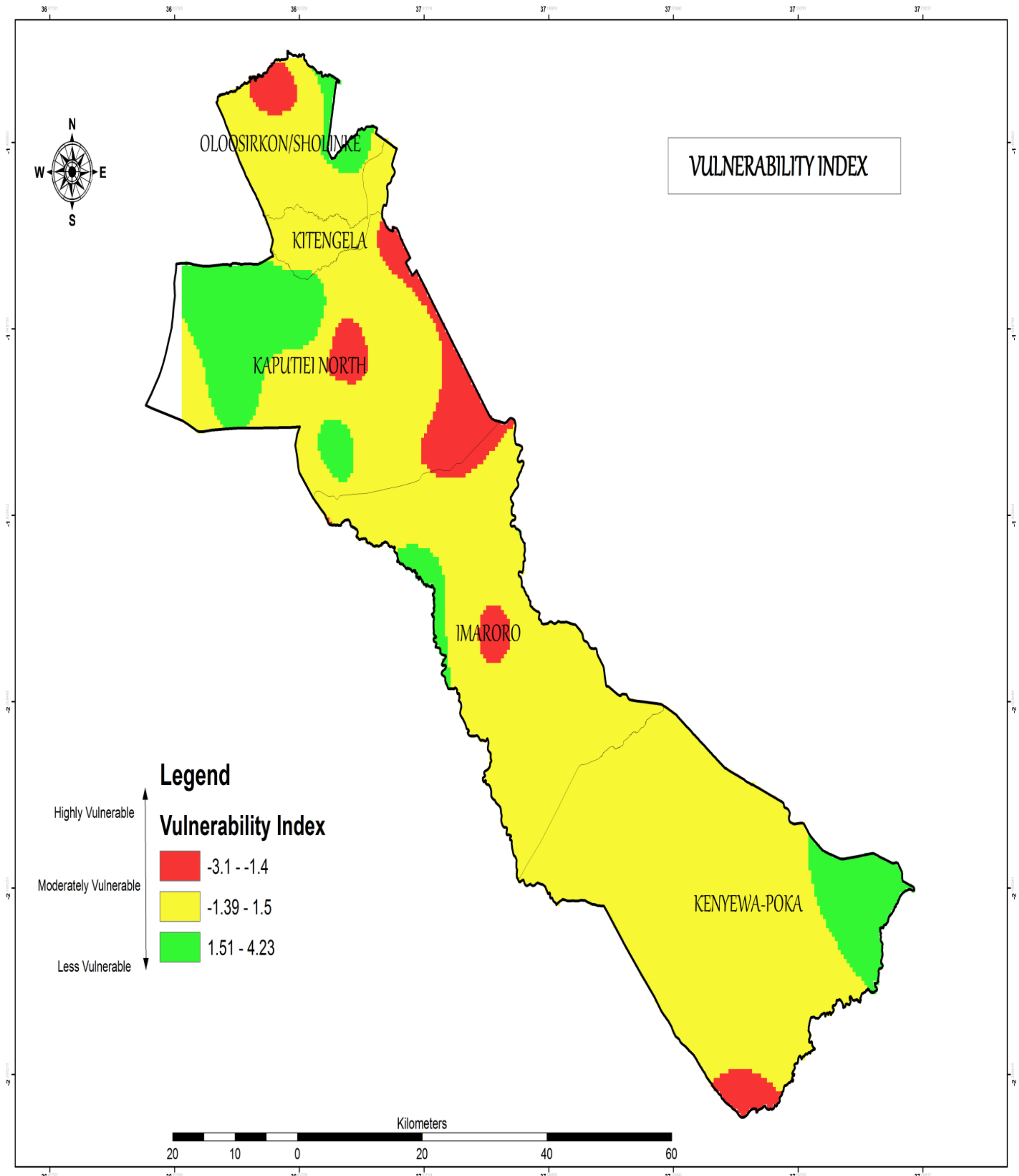

Figure 7.2: Map showing the level of vulnerability of communities in Kajiado East to climate change and variability by wards

The households that are highly vulnerable are unable to cope with the adverse effect of climate change and variability and needs immediate external assistance in terms of relief to survive. Previous studies in ASALs of Kenya (Orindi *et al*., 2007; Omolo 2010; Amwata, 2013) reported that it is becoming difficult for households to recover from changing and inconsistent weather conditions affecting the pastoralist livelihood. The results is also consistent with the findings of Opiyo *et al*., (2014); and Ongora and Ogara (2012) which were conducted in similar ecosystem in Kenya.

7.7 Factors influencing household vulnerability in the study area

The result of the ordered logistic regression model for the variables influencing the vulnerability of household is presented in Table 7.7. A total of nine variables had significant influence (at 5% and 10% levels of significance) on vulnerability to climate change in the study area. The result shows that gender of household head, years of experience in the area, educational level, visit by extension agents, herd size, livestock diversity, land size and livestock mobility has significant influence on vulnerability in the study area.

The Maasai communities are typically patriarchal and female headed households, households that have no access to extension agents and those with low level of education are significantly vulnerable to climate change. This is because such households either lack access to information for early decision making during extreme climatic events or lack the economic capacity to act on decisions during extreme conditions.

Several studies (Tesso *et al*., 2012; Opiyo 2014) conducted in pastoral communities in Eastern Africa reported that female headed households are usually not empowered enough to take decisions during extreme climatic events such as drought and are frequently without access to credit services and adequate capital assets. They are also not able to own large herds to manage household's daily requirements. This shows the need to specifically target pastoralist women in climate change adaptation planning in arid and semi-arid lands of Kenya. This study also concurs with Blench (2000) which reported the significant influence of level of education on vulnerability in similar ecosystem.

Table 7.7: Factors influencing households vulnerability to climate change and variability

Variables	Estimates	SE	OR	Z	P-value
Gender of HH head: female headed HH	1.96	0.55	5.34	3.56	0.029*
Age of HH head: 50+years	0.028	0.96	0.083	0.029	0.77
Experience in the area: 45+years	0.49	0.039	1.409	12.24	0.066**
HH size: 5persons and above	0.02	0.37	0.051	0.057	0.954
Educational level: no primary education	0.751	0.65	2.175	1.269	0.077**
Dependents:5+persons	-0.127	0.137	0.372	-0.922	0.357
Marital status: Single (including divorced and widowed	-0.811	0.951	2.312	-0.853	0.093**
Visit by extension officers: no access to extension services	-1.501	0.476	4.501	-1.217	0.0898**
Receive climate information	1.099	0.876	4.439	1.632	0.672
Crop-farming income: with income from crop farming	0.803	1.540	2.804	0.522	0.60182
Non-farm income: with income from non-farm activities	0.145	1.303	0.335	0.112	0.91111
Herd size: 100+ total herd size	0.0185	0.006	0.049	2.906	0.00366*
Livestock diversity: own 2+ domestic animal types	0.535	0.662	1.535	1.807	0.08194**
Land size: own 100+ acres	0.0084	0.003	0.018	3.055	0.00225*
HH members employed: 3+ members employed	-0.189	0.402	0.385	-0.46	0.64561
Credit access: have no access to credit	-0.953	0.251	2.954	-0.962	0.746
Livestock mobility: able to move livestock freely	0.933	0.203	2.903	4.775	0.083**
Temperature: noticed increase	-0.841	1.821	-241	-0.462	0.644
Rainfall: noticed decrease	-0.049	0.675	0.123	-0.432	0.876
Drought: experience drought within the last 10 years	-0.342	0.865	1.497	-0.329	0.716
Floods: experience floods within last the 10 years	-0.012	3.215	0.042	-0.004	0.996
Drought frequency: every year	-0.291	0.751	1.292	-0.388	0.698
Floods frequency: every year	-1.536	0.664	2.154	-2.318	0.817

SE = standard error, OR= odd ratio, z is score of two sample test. The statistical significant of the p value was expressed at 5%*, and 10% **

The significant influence of herd size, livestock diversity, access to credit, land size and livestock mobility is also reported in this study. These factors enhance the ability of households to cope during extreme climatic events and reduce their vulnerability to climate change and its extremes. This agrees with studies by Eriksen *et al.* (2005) and Notenbaert *et al.* (2013) who also reported some of these factors as key determinant of household vulnerability to climate variability and change in rural communities. The results are also consistent with previous studies by Kakota *et al.* (2011) and Opiyo (2014) which were conducted in similar ecosystems.

7.8 Conclusion

This study used socio economic and biophysical indices developed jointly with the Maasai communities to analyze household vulnerability in the administrative wards in Kajiado East sub-County. These indices are useful for development planning and resource allocation to the wards and communities. Categorization of vulnerability levels using maps is also useful for government both at the National and County level for identifying the highly vulnerable communities for research based adaptation planning and efficient resource allocation to the wards. Human adaptive response to climate change occurs at the local and household level where the climate variability is experienced. It is therefore crucial to understand vulnerability at the household level for timely intervention and also for development of evidence based policies that will lead to effective adaptation programmes for long term resilience. Household vulnerability analysis enables policies and interventions to be targeted the most vulnerable places or people, and allows for well defined adaptation options.

Most of the respondents in this study identified drought and dry spells as the most common climatic extreme in Kajiado County. The increase in the frequency of dry spells and drought over the last few decades in Kajiado County is increasing the vulnerability of Maasai pastoralists to climate change and variability. The level of vulnerability of household in the study area is directly related to their dependence on natural resources such as pastoralism. This is because the use of such natural resources is dependent on rainfall, which is projected to change.

The vulnerability map shows that households in Kitengela ward which is the most developed ward in terms of access to basic amenities is the least vulnerable ward in Kajiado East sub County. Results also shows that indicators such as gender of household head, level of education, access to credit facilities, access to extension services and herd's mobility significantly affects vulnerability of Maasai pastoralists to climate change. It is therefore necessary for government at all levels to develop policies and programmes that will address the huge infrastructural deficit in Kajiado County, as this will not only reduce vulnerability to climate extremes, it will also reduce the huge poverty level which currently stands at about 50% (GOK, 2013).

The study concludes that there is disparity in the vulnerability levels of households within communities and also among wards in Kajiado East sub County. Resilience intervention should therefore be specific, targeting wards within the Counties and also particular households within the communities. Interventions such as women empowerment, access to extension agents, provision of basic infrastructures such as electricity, water, and good roads, free herd mobility and access to credit facilities will increase resilience of Maasai pastoralists in Kajiado East to the effect of climate change and variability.

CHAPTER EIGHT

ADAPTATION STRATEGIES OF MAASAI PASTORALISTS TO CLIMATE CHANGE AND VARIABILITY IN KAJIADO COUNTY

8.1 Introduction

Geographical location is one of the key factors that determine vulnerability of communities to climate change and variability (Serigne and Verchot, 2006). Over 80% of the lands in Kenya are classified as arid and semi-arid lands (ASALs) and they are by far the most vulnerable to climate change and variability (Opiyo, 2014).

Kenya has identified its ASALs as the most vulnerable areas to climate change with huge impacts on livestock rearing, small-holder agriculture and tourism, which are the dominant sources of livelihoods in these areas (GOK 2009). About 10 million people who are about a third of the whole population of Kenya live in the arid and semi arid lands (ASALs). Livestock production (largely through Pastoralism) is the main source of livelihood in ASALs. Livestock serve many roles in pastoral society. Livestock production serves as both the means and outcomes of production, as sources and objects of labour and as social, cultural and capital goods (Galaty and Johnson, 1990).

Repeated occurrences of the incidents of droughts and dry spells have made it difficult for the pastoral communities in the ASALs to maintain their assets. Also lack of timely early warning information has reduced their capacity to respond when the conditions are still good. Drought is the major climatic hazard affecting agriculture and livelihoods in ASALs of Kenya. It ranks first among naturals hazards in the number of persons affected in Kenya and Africa (UNDP/BCPR 2004; UNEP 2002). Drought and dry spells has a major devastating impact on the economy of the pastoralist communities in Kajiado County. The County has experienced major incidence of drought since 1900, which have become more common in the last two decades (Kagunyu, 2014). Severe drought have been recorded in the following years 1960/1961, 1969, 1973/1974, 79, 1980/1981, 1983/1984, 1991/1992, 1995/1996, 1999/2000, 2004/2006, 2008/2009, and 2010/11 with widespread direct and indirect effects on the lives and livelihoods (Osano *et al.* 2013;

Huho and Kosonei 2014). The impacts of recurrent droughts and dry spells pose considerable challenges on the people of Kajiado County. The impacts of droughts on pastoralist communities are manifested mainly through livestock mortality, water scarcity and land degradation. This impact is amplified by increasing human population, privatization of communal lands, weak governance, and reduced adaptive capacity of the households. These processes jointly heighten vulnerability of pastoral communities and increase their poverty level.

Adaptation is a wide concept covering actions taken by individuals, households, communities, private and public organization. Successful adaptation can reduce vulnerability by strengthening existing coping and adaptation strategies. For many decades, pastoral communities in ASALs have developed indigenous ways of adapting to varying degree of occurrence of dry spells and drought. However, recent increase in the frequency of occurrence of these weather events is stretching the resilience of the pastoral communities. Pastoral communities have for a long time used indigenous forecasting methods to predict seasonal climatic events (Winnie *et al*., 2002). Some of the Maasai pastoral communities observe clouds, wind and lightning that likely have their origins in traditional understandings of what contemporary researchers recognize as atmospheric science. Others watch the behaviour of livestock, wildlife and the local flora (Amwata, 2013). However, many traditional forecasting methods are perceived as becoming less reliable with increasing climate variability and unpredictability

Studies (Silvestri *et al.* 2012; Osano *et al.* 2013; Amwata 2013; Opiyo 2014) have analyzed and documented pastoralists' adaptation and coping strategies to climate change and variability at the community and household level. Given the projections for increasing drought impacts in the pastoral areas, it is important to inform policy makers on various adaptation and coping responses at local levels in order to reduce risks associated with drought. This study seeks to understand impacts of climate change on the pastoralist communities, and documented coping and adaptation strategies used by the pastoralist communities. Viable adaptation strategies for enhancing adaptation of the

Maasai pastoralist communities to climate change and variability were identified in a participatory approach involving the communities and other stakeholders

8.2 Socio-demographic information of respondents

8.2.1 Educational level of respondents

The educational level of respondent (Table 8.1) shows a high level of illiteracy among Maasai pastoralist in Kajiado County. Fifthy percent (50%) of female and 31% of male respondent had no formal education. This shows a higher level of illiteracy among Maasai women when compared to men. Illiteracy hinders access to information and limits speed of recovery from a climatic events; it also constraints options for livelihood diversification (Omolo, 2010; Kanguyu, 2014). Thirty eight (38%) of female and 49% of male respondent had primary education; 13% of female and 13% of male had attained secondary education; 3% of males had diploma degree and 2% of the male respondent had University degrees. This concurs with the findings of (Ongoro and Ogara, 2011; and Kanguyu 2014), who reported high illiteracy levels among pastoralists in Kenya. GOK, 2013, also reported a high illiteracy rate of 65.2% for Kajiado County. Illiteracy limits the ability of an individual to take up opportunities such as employment and inhibits access to information and technical advice that could enhance adaptation to climate change.

Table 8.1: Educational level of respondents

Gender	Informal Education	Primary Education	Secondary Education	Diploma	University	Others	Total
Female	50%	38%	13%	0%	0%	0%	100%
Male	31%	49%	13%	3%	2%	1%	100%
Average	40.5%	43.5%	13%	1.5%	1%	0.5%	100%

8.2.2 Access of respondent to basic infrastructure

The basic asset owned by the respondents (Table 8.2) shows that 94% of Maasai pastoralists interviewed had radios, 64% had television sets, 86% had mobile phones, only 21% has access to government electricity, 68% of the household has toilet facilities and 85% had access to basic health facilities. The high percentage of respondents with radio shows that it should be good and effective means of communicating vital information in the pastoralist community. There is also need for government to expand electricity to rural areas. This will create alternative sources of livelihood in the rural areas and also improve their access to information. The findings of this study concurs with (GOK, 2012) which reported that only 39.8% of households in Kajiado County had access to electricity and most of them were in the urban areas.

Table 8.2: Asset owned by respondents and basic infrastructure respondent can assess

Asset owned by respondent	Yes (%)	No (%)
Radio	94	6
Television	64	30
Mobile phone	86	14
Electricity	21	73
Toilet	68	26
Basic health	85	15

8.2.3 Sources of livelihood of respondents

The sources of livelihood of respondents are presented in Figure 8.1. The results show that 93% of respondents were involved in livestock keeping (pastoralism). Several studies (Bryan *et al*., 2009; Rao *et al*., 2011; Silvestri *et al*., 2012; Opiyo 2014) had reported that pastoralism is the main source of livelihood in ASALs and that pastoralist has developed mechanisms to cope with climate variability over the years. However, increase in extreme climatic events such as drought in recent decades has triggered adoption of alternative sources of livelihood among pastoral communities. This study shows that 66% of respondents were involved in business and leather works, the study also shows that 8% of respondent were government employees, 7% were involved in crop production and 1% were employed as tourist guards and home guards.

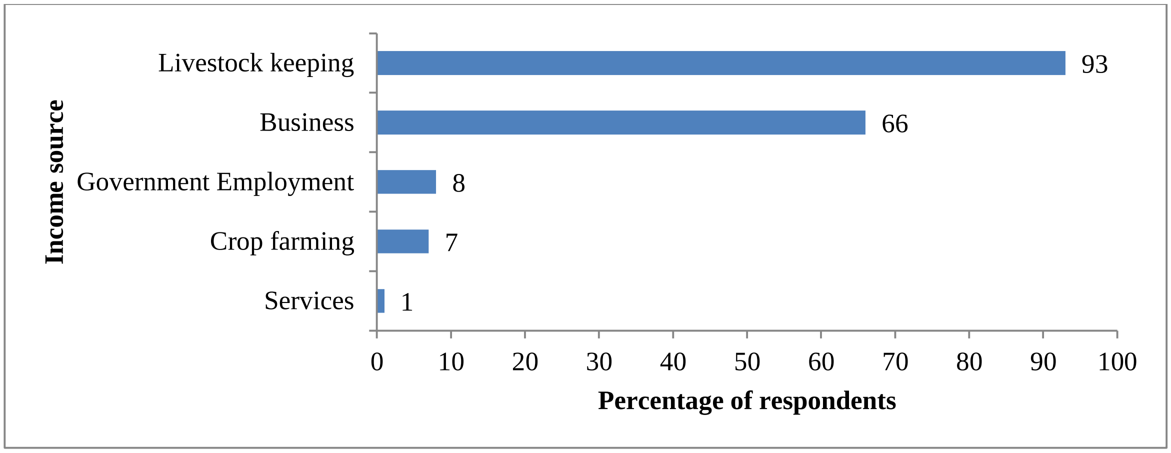

Figure 8.1: Sources of Livelihood for respondents

8.3 Impacts of Extreme climatic events on pastoralist communities in Kajiado County

Climatic related extreme events have over the years been a major concern in the arid and semi-arid lands of Kenya. These events especially drought most times lead to loss of livestock and human lives with severe social, economical and environmental consequences.

A five point rating scale was used to determine the impact of climate change on pastoralist communities in Kajiado County. The 5 point ordinal scale were graded either as 5= very high impact, 4= high impact, 3= moderate impact, 2= low impact 1= no impact. Table 8.3 shows that the impact of climate change is felt most by Maasai pastoralist in Kajiado in the following areas: (1) Pastoralist livelihood (2) Vegetation change (3) Livestock specie change (4) Human and animal health (5) child education (6) Land use change (7) Eating habit and food security.

Table 8.3: Impact of climate change on pastoralist community

Kind of impact	% Respondent				
	Very high	High	Average	Low	No
Pastoral livestock keeping	39.8	33.6	17.5	6.8	2.2
Eating habit and food security	29.8	35.9	30.4	2.5	1.4
Human and animal health	30.5	39.2	20.0	9.1	1.2
Vegetation change	28.6	38.9	22.3	7.0	3.2
Livestock species	22.6	35.8	30.4	6.2	5.0
Child education	22.6	29.7	37.9	5.0	5.2
Land use change	11.2	29.8	38.4	15.0	5.6

8.3.1 Impact of climate change on pastoral livestock keeping

About 40% of respondents stated that climate change had a very high impact on the pastoral way of keeping livestock, while 33.6% reported a high impact of climate change on pastoral livestock keeping. This shows that pastoralism which is main source of livelihood among Maasai is severely affected by climate change. Drought which is the major climatic extreme event in Kajiado County is causing fluctuations in the livestock populations through increased mortality, and reduced birth rates due to decreased forage and water availability.

Severe droughts force pastoralists to reduce their livestock numbers out of desperation in order to provide food for their families. Selling of livestock by pastoralists was taken as the last option during drought. Unfortunately, livestock become emaciated during drought and do not attract competitive price from the buyers. A key informant stated that the prices given to pastoralists for their livestock during drought were very poor. Some community members were not willing to sell their animals and they preferred to let them die. The issue of land subdivision and fencing in Kajiado also aggravates the effect of climate change on the pastoralist system. Movement of animals during drought has been reduced due to land division and it is having severe impact on the pastoralist livelihood in Kajiado County.

Focus group discussant agreed that the pastoralist livelihood is threatened in Kajiado County. They agreed with one of them who said that:

"Although Maasai are known worldwide as pastoralist, however, the rate at which drought and dry spell is increasing and also the continuous sales and fencing of land will most likely lead to the end of pastoralism in Kajiado County within the next 20years." He further said that *Maasai are making sure their children are educated so as to effectively prepare them for a future outside the pastoralist system"* (FDG Olturoto, Kajiado East).

Several studies (Howden 2009; Huho *et al*., 2012; Kagunyu 2014) have reported the severe effect of drought on the pastoralist system in ASALs in Kenya. Amwata (2014) reported that the frequent drought in Kajiado have led to considerable loss of livestock, demoralizing the Maasai from restocking their herds.

8.3.2 Impact of climate change on food security and eating habit

Table 8.3 shows that climate change is affecting food security and eating habit among Maasai pastoralist in Kajiado County. About 29.8% of respondents reported that climate change has a very high impact on food security and eating habit, 35.9% reported high impact, 30.4% reported average impact, 2.5% reported low impacts and 1.4% reported no impact. Maasai pastoralists were known for eating meat, drinking milk and blood. However, recurrence drought has lead to severe loss of livestock and reduction on milk availability. Some pastoralists have embraced agro-pastoralism as an adaptation option against drought and dry spell while others depend on food aid from government, NGOs and faith based organizations. Although relief food was not a desired option, respondents reported that helplessness during and after droughts left them mainly dependent on it for survival. The effect of drought is felt more by nursing women and young children who cannot easily migrate in search of alternative sources of income and who need good nutrition for survival. Orindi *et al*., (2007) and Kagunyu (2014) reported the effect of drought on food security in ASALs of Kenya. Amwata (2014) also stated that climate variability and change is a major threat to food security in Kajiado County.

According to information gathered from focus group discussions, a local meal called *githeri* (maize and beans) has become very common for all, including young children. The reason they gave for this was that drought has contributed to diminished cow nutrition due to reduced forage production which, in turn, has led to reduced daily milk trade off. Also wild fruits which used to be alternative sources of food are no longer available. The FGD agreed with one of them who said:

"Wild fruits such as ololoipichi, lokua and ngosingosi were readily available when they were young and the Maasai usually fed on them when there was shortage of food or during migration. He said the changes in climate and land use have destroyed the trees and the fruits are no longer available."

8.3.3 Impact of Climate change on Human and animal health

The direct and indirect impacts of climate change on human and animal diseases have been reported by many studies (Bossche and Coetzer, 2008; Wandinga *et al*, 2009; Kagunyu, 2014). About 30.5% of respondents reported that climate change had very severe impact on human and animal health and 39.2% reported severe impact of climate change.

The respondents reported the emergence of new diseases such as rift valley disease which were not common in the County. There were also report of increase in diseases such as Foot and mouth disease, Nagana and Anthrax. Migration of animals in search of pasture during drought leads to contact of livestock with wild animal and causes emergence of new and deadly diseases among livestock. This finding agrees with Wandiga *et al*., (2009), observations that climate variability may bring about substantial shifts in disease distribution, while outbreaks of severe diseases could occur in previously unexposed animal populations. It is also importance to note that while livestock often has evolved genetic resistance to diseases to which they are commonly exposed, they may be highly susceptible to new diseases.

This study also revealed that climate variability has led to increased human diseases. This finding concurs with that of Wandiga *et al*., (2009) and IPCC (2014) which stated that global changes in temperature and rainfall may affect the incidence and range of several infectious diseases within endemic areas and their introduction to other areas. Kanguyu (2014) indicate that direct effects of climate change, which include higher temperatures and changing precipitation patterns, could cause increase in the spread of existing vector-borne diseases and macro parasites, accompanied by the emergence and circulation of new diseases. In some areas, change in climate could also generate new transmission models. The diseases identified by respondents in this study included Malnutrition amongst children, Kwashiorkor, cholera that is caused by shortage of water, diarrhea, dysentery and typhoid. Some respondents also claimed that changes in food pattern have lead to increase in cancer cases in the community. This result shows that most of the diseases listed by respondents were directly or indirectly linked to shortage of food or water which is usually common during drought periods. This further confirms the impact of extreme climatic events on human health and buttress the need to develop adaptation strategies that will reduce the adverse effect of extreme climatic events on human health.

8.3.4 Impact of climate change on vegetation change

Table 8.3 shows that 28.6% of respondent believed that climate change had a very high impact on vegetation change, 38.9% reported high impact, 22.3% reported average impact, 7.0% reported low impact and 3.2% reported no impact. Respondents stated that increase in drought frequency has lead to over grazing of the lands and the grass does not have enough time to regenerate. They indicated that this has lead to the disappearance of valuable perennial forages such as *Sirgirso* (*Acacia reficiens*) and Cynodon spp. They also reported the emergence of wild weed such as utiamerititi (*Ipomea Kituensis*) which is not that useful to the livestock. The disappearance of wild fruits such as *Ololoipichi*, *Lokua* and *ngosiingosi* was also observed by the respondents. Explaining the impact of climate change on vegetation, one of the FGD participants stated that:

"In the past, this area was covered with grass and trees which we use to cut for our animals especially during dry seasons. Today, most of grassland has been degraded due

to over grazing and others have sold and fenced their lands" (FGD Olenkotila, Kajiado East).

This study agrees with Nduma and Warui (2001), and Kagunyu (2014) which indicates that the increasing frequency of droughts in ASALs in Kenya has impacted negatively on the gathering of leaves, seeds, barks and tubers which used to supplement the family livestock based diet particularly during times of deprivations.

8.3.5 Impact of climate change on livestock species

Table 8.3 shows that 22.6% of respondent believed that climate change has very severe impact on livestock species, 35.8% believed it has high impact, 30.4% believed it has average impact, 6.2% reported low impact while 5.0% reported no impact. The Maasai pastoralists are gradually changing the breed of animals due to effect of extreme drought and others are rearing new species of animal that were not usually associated with the Maasai. Respondents reported that new breeds such as Shaiwal cattle, dairy goats and black headed Maasai sheep are now been reared by Maasai pastoralists in the area. They reported that dairy goats consume less forage when compared to cattle and they are also good producer of milk. Focus group discussants stated that small ruminants were easy and cheap to restock after a disaster. This argument agrees with Kagunyu (2014) which states that livestock keepers have started rearing small ruminants as an adaptation measure against climate change. It was also reported that some Maasai households especially women were now rearing chicken in large scale. This practice was not common in the Maasai land some decades ago.

8.3.6 Impact of climate change on child education

Several studies have reported education as one of the most effective no regret climate change adaptation option in the ASALs of Kenya (Omolo, 2010; Opiyo 2014; Amwata 2014). Education provides a viable alternative source of livelihood to the pastoralist communities. Respondents reported that increased frequency of drought in the study area which usually has a severe financial impact on households is causing an increase in the number of school drop out in the area. Children usually drop out of school to assist their households during drought.

8.4. Adaptation and coping strategies of Maasai pastoralist to climate change and variability

The Maasai pastoralist communities in Kajiado County have developed strategies of coping and adapting to climate change and its extreme over the years. However, respondents agreed that increase in frequency and magnitude of extreme climatic events is increasing their vulnerability to these extreme climatic events. This study revealed the different strategies used by Maasai pastoralist to adapt to climate change and its extremes. Table 8.4 summarizes the adaptation and coping strategies and the percentage of households using the adaptation strategies in the study area. Migration in search of pasture (79%), Destocking (68%), buying of hay (60%), livelihood diversification (74%), table banking and self held group (55%) were some of the strategies identified by the respondents. Other strategies identified by the households include harvesting of wild fruit, slaughtering of weak animals, diversification of herds, sending children to school and rain water harvesting.

Table 8.4: Adaptation and coping strategies to climate change and variability

Adaptation/coping strategy	% of household
Migration	79
Destocking	68
Buying hay	60
Paddock grazing	55
Diversify livelihood (employment, bead making, tourist guide)	74
Table banking and self help group	55
Irrigated farming using borehole	25
Selling of land	27
Rain harvesting	35
Sending children to school	63
Tree planting	39
Building dams	23
Greenhouse farming	8
Diversification of herds	58
Animal health training	54
Food aid	38
Slaughtering of weak animals	45
Harvesting of wild fruit	59

Source: Field study

8.5. Identified best adaptation options in the study area

The Maasai households were asked to rate the adaptation strategies identified based on their level of importance. They rated the adaptation strategies that will significantly reduce their vulnerability to climate change and also areas where they will need assistance from external bodies such as government organizations and NGOs. A five point rating scale was used to rate the level of importance of the adaptation strategies to the Maasai pastoralist households in Kajiado County. The 5 point ordinal scale were graded either as 5= very important, 4= important, 3= moderate importance, 2= low importance, 1= no importance.

Table 8.5: Importance of Adaptation strategies used by the Maasai

Adaptation strategies	% Respondent				
	Very important	Important	moderately	Low	No
Rain harvesting/water resource development	62.00	25.4	10.8	1.8	-
Child Education	45.6	35.8	9.5	7.2	1.9
Improved infrastructure	42.6	36.8	10.4	5.6	4.6
Herd mobility	32.4	35.8	15.0	8.2	8.6
Promote table banking and cooperative organization	33.8	32.4	21.5	10.9	2.3
Livestock diversification	30.0	32.8	25.4	8.0	3.8
Early warning system	30.4	30.6	26.8	7.9	4.3

Source: Field study

8.5.1 Rain water harvesting and water resource development

Respondents identified water shortage as the biggest problem facing Kajiado County. Table 8.5 shows that respondents believed that solving water problem through water resource development such as sinking boreholes, constructing dams and water pans is a very important adaptation strategy in Kajiado County. About 25.4% reported that it is important, 10.8% reported that it is moderately important and 1.8% reported low importance. Lack of water for both human and animal use is a major challenge in Kajiado County. This challenge is further compounded by frequent drought that leads to drying up of water pans, wells and rivers. Rain water harvesting, traveling long distance to fetch water and buying of water are some the adaptation strategy used by pastoralist. The importance of solving the water shortage was echoed by the FGDs with one of the discussant stating:

"Lack of water is one of the biggest challenges facing Kajiado County. We need the government and NGOs to assist in building boreholes, dams and water pans for us and our livestock. This will stop the water borne diseases affecting people and also save our women and children the danger of traveling long distance in search of water."

8.5.2 Child education

The interviewed households believed that child education is a long term adaptation strategy to climate change. They perceive education as a viable livelihood diversification strategy in a fast changing society that is making sustainability of pastoralism in the County uncertain. Table 8.5 shows that 45.6% of respondent reported that child education is a very important adaptation strategy, 35.8% believed it is important, 9.5% believed it is moderately important, 7.2% said it's of low importance and 1.9% said it is of no importance. For decades the Maasai have viewed education as an exit strategy and have been keen in educating their children. However, with increased in urbanization, change in land use and increased climatic extremes, child education is now seen as the best way to prepare for an uncertain future. Previous studies by Opiyo et al., (2014) and Kagunyu (2014) also reported child education as a viable adaptation option in ASALs of Kenya.

8.5.3 Improved infrastructure

The respondents believed that improved road network and availability of electricity will improve their resilience to climate change and variability. About 42.6% of respondent stated that improved infrastructure is a very important adaptation strategy and 36.8% believed it is important. GOK (2013) reported that Kajiado County had only 300km tarmac road out of the 2,344.2km road in the County; it also stated that about half of the available road network (1111.9km) are earth roads. Improved road network will improve access to major town to seek for alternative sources of income by the pastoralists. It will also increase access to major markets in the County. Only 39.8% of the households in Kajiado County have access to electricity and they are mainly concentrated in the urban areas (GOK, 2013). Access to electricity especially in the rural areas will improve their access to information and early warning systems that will help make fast decisions during climatic extremes. Respondent also reported that electricity will enhance livelihood diversification especially into electricity based livelihood.

8.5.4 Herd mobility

Herd mobility is one of the main coping strategies used by pastoralist particularly in times of drought and dry spell. About 32.4% of respondent reported that herd migration is a very important adaptation strategy and 35.8% reported it as an important adaptation strategy. Herd mobility enables strategic use of resources and help to minimize the effect of drought and dry spells (Opiyo, 2014). Mobility is traditionally part and parcel of the Maasai livelihood strategy employed to access pasture, water and market for livestock. In times of extreme drought, pastoralists graze their animals in restricted national parks and sometimes cross the border to Tanzania in search of pasture and water. Focus group discussant reported that herd migration in Kajiado County is reducing due to increasing land sub division and sales; and increase in the chance of disease outbreak and death of animals during migration. FGD participant suggested that it is necessary to create of livestock migratory routes in the County. This will allow pastoralist move their animals freely during drought and dry spells. Studies (Ellis and Swift, 1988; Little and Leslie, 1999) revealed that seasonal decisions to migrate ensure that households maintain the productivity of their herds and security of their families. This form of mobility is pursued primarily for livelihood purposes and is very strategic to the survival of the pastoralist system (McCabe, 2006).

8.5.5 Table banking and Cooperative societies

Table banking is a group funding system where members of a particular group meet regularly to save money, repay loans and other contributions and also borrow money as long term or short term loans (FGD, Entayiankat). 33.8% of respondent reported that table banking and cooperative society are very important adaptation strategies during extreme climatic events. Table banking and cooperative societies is a fast way of securing loans without collateral and also minimal interest rate among rural dwellers. The Maasai women in Kajiado County use table banking to secure loans for livelihood diversification and paying for children school fees.

8.5.6 Livestock diversification

Table 8.5 shows that 30.0% respondents reported that livestock diversification is a very important adaptation strategy in the study area, 32.8% reported that it is important, 25.4% reported moderate importance, 8.0% reported low importance and 3.8% said it is of no importance. Livestock diversification is one of the key traditional adaptation strategies that have enabled pastoralist communities to survive harsh environmental conditions for centuries (Sperenza, 2010). Diversification of livestock herds has both ecological and economic implications as different livestock species have different water and pasture requirements and react differently to droughts and diseases. Respondents reported that new breeds that are drought tolerance and consumes less pasture such as Sahiwal cattle, dairy goats and black head persian sheep are now been reared by Maasai pastoralist in the area. They reported that dairy goats consume less forage when compared to cattle and they also produce nutritious milk.

8.5.7 Early warning system

Early warning against extreme climatic conditions gives communities ample time to make decisions (Ogallo, 2004; ICPAC 2007; Amwata, 2013). Result shows that 30.4% of respondents percieved that early warning system as a very important adaptation strategy in the study area. Participants at the FGD agree with the statement made by one of them that:

"Timely and reliable climatic information would enable the Maasai households to make informed decision on whether to increase theirs herd or sell part of them. It also helps to make decisions on the species of livestock to retain, and also useful in making important agricultural decisions by agro-pastoralist."

However, the respondents complained that climatic information does not get to the communities early. They also complained about the accuracy of climatic information from government sources. The pastoralist communities suggested the use of available technologies such as mobile phone for climate information dissemination. For early warning information to be effective and more than just a projected events, communities need to be endowed with a wider range of information and capacities upon which they can rely to mitigate imminent crises. A clear understanding of the knowledge and experience of communities can guide early warning information and services content in such a way that valuable information can be provided at the grassroots level. Early warning information should include provision of seasonal climate and disease risk forecasts, timely information on the distribution of prices of key commodities across major markets and provision of information on the geospatial distribution of forage and water availability; it should also offer advice on effective and available risk mitigation strategies and how best to respond in the advent of a shock.

The use of community radios to promote drought early warning system among pastoralist in Isiolo County in northern Kenya is a good example of community based early warning system (ISDR, 2010). The vastness of land in most Maasai communities and poor infrastructure substantiates the use of community radio as an effective tool for effective early warning system in pastoralist communities.

There are other adaptation strategies that can increase resilience of pastoralist to climate change and variability that were not identified by the communities in this study. Index based livestock insurance (IBLI) can also be an effective means of enhancing resilience of pastoralist to the impact of climate change and variability. Formal insurance, especially against covariate livestock loss, is rarely available and not effective for pastoral households due to barriers such as covariate risk, high transaction costs and asymmetric information. Index based livestock insurance (IBLI) presents an opportunity to overcome these barriers. In contrast to traditional insurance, which makes insurance payments based on the actual loss of what is insured, IBLI payout is based on an objective and transparent index (e.g., rainfall, predicted livestock loss based on a measured vegetation condition) that is strongly associated with insurable loss but cannot be influenced or varied by both contract parties.

The International Livestock Research Institute (ILRI) has implemented an IBLI pilot in the Marsabit district of northern Kenya. The index is based on the Normalized Difference Vegetation Index (NDVI). By addressing the constraints of covariate risk, asymmetric information and high transactions costs that have precluded the emergence of commercial insurance in these areas to date, IBLI offers a novel opportunity for the deployment of financial risk transfer mechanisms for pastoralists. The basic design is replicable and can be applied in other locations like Kajiado County where covariate risk exposure is significant and existing insurance products do not adequately meet household insurance needs.

Other adaptation strategies that have been successfully used in arid and semi arid lands that can also be used to enhance pastoralist livelihoods in Kajiado County are community based rangeland rehabilitation, pasture reseeding, development of fodder banks and improved livestock marketing programme.

8.6 Role of external organization in enhancing adaptive capacity of Maasai pastoralist to climate change

The role of government agencies, NGOs and faith based organizations in enhancing the adaptive capacity of the Maasai to climate change is presented in Table 8.6. Respondents reported that government organizations such as National Drought Management Authority (NDMA) give early warning during extreme climatic events. They also reported that the national government provides food especially maize during extreme droughts. They however stated that the quantity of food relief is usually very small compared to the devastating effect of the droughts. Respondents reported that most government interventions are reactive and short term, and not adequate to address the enormous challenges facing pastoralist in ASALs in Kajiado. Respondents stressed the need to concentrate on long term projects such as drilling boreholes and constructing water pans, providing infrastructures such as good roads and electricity, and also providing irrigation facilities for agro pastoralists.

NGOs play crucial roles in enhancing adaptive capacity of pastoralist in the study area. Some of the roles identified by respondents includes (1) Educating pastoralists on climate change adaptation (2) Give relief food (3) Help in sponsoring children to school (4) Give tanks to households for water harvesting (5) pay medical bill of children. Respondents also reported that some faith based organizations also provide food and clothing during extreme droughts.

There is need for government and development partners to find comprehensive long term strategies to address the challenge of climate change in ASALs in Kenya. Low level of development and lack of basic infrastructure is a big challenge to most pastoralist communities. Addressing the challenge of infrastructure mainly good roads, water and electricity will enhance the adaptive capacity of most pastoralist households to climate change and variability.

Table 8.6 External contribution to climate change adaptation in the study area

Organization	**Contributions**
Government organizations	
National Drought Management Authority	Provide early warning information during drought
	Give advice of when to plant
	Advice of when to destock and price of animals
Kenya Meat Commission (KMC)	Buy weak animals during extreme drought
Government of Kenya	Provide food relief during drought
	Assist in restocking after extreme drought
Non Governmental Organizations (NGOs)	
	Provide early warning information
	Educate pastoralist on adaptation strategies
	Give relief food during drought
	Sponsor children to school
	Give water tanks for rain harvesting
	Pay for children’s medical bills
Churches and other faith based organizations	Provide food and clothing’s especially to Orphans
	Pay for medical bills.
	Pray for drought to end

8.7 Conclusion

The results showed that the impact of climate change and its extremes is being felt by the Maasai living in Kajiado County of Kenya. The increase in drought occurrence has severe impact on pastoral livestock keeping, food security, human and animal health, vegetation, and child education in the study area. The Maasai communities have always responded to climate variability using various strategies that are discussed in this chapter. Adaptation strategies such as migration, destocking, buying hay, rain harvesting selling land and many others are used by pastoralist to enhance their adaptation to climate change and variability. However, most of these adaptation strategies adopted by the pastoralists are largely autonomous and reactive adaptation and are unlikely to withstand the projected magnitude and scale of climate change in the 21st Century. Moreover, the vulnerability of the Maasai pastoralist is exacerbated by the interaction among 'multiple stresses' including poverty, land use change and a low adaptive capacity (Maito *et al*., 2013). Planned adaptation actions such as Index Based Livestock Insurance (IBLI), integrated early warning system, improved livestock marketing programme and rangeland rehabilitation are therefore needed to respond to current and anticipated impacts of climate change and variability among pastoralist in the arid and semi-arid lands of Kenya.

In conclusion, the projected impact of climate change and variability in arid and semi-arid regions of Kenya requires planned adaptation strategies that will enhance the resilence of pastoralist to climate change and variability. Various stakeholders such as the government, communities, non-governmental organizations and the private sector all have important roles to play in enhancing the adaptive capacity of pastoralist to climate change and variability.

CHAPTER NINE
GENERAL CONCLUSION AND RECOMMENDATIONS

9.1 Conclusions

This study has revealed high temporal and spatial variations in annual and seasonal rainfall in Kajiado County. The high spatial variation in rainfall shows that sub-counties in Kajiado are impacted differently by climate related events such as droughts and dry spells. It is therefore important that adaptation strategies to climate change and variability in Kajiado County should be location specific for it to be effective. The results show that rainfall in Kajiado County is highly influenced by altitude with areas of high altitudes like Ngong having annual rainfall that are more than twice the annual rainfall of lowlands like Magadi. It is however important to note that climate variability is not only about negative impact as it also present vast opportunities for livelihood diversification, proper and effective land use and management. Arid and semi-arid lands present an opportunity for pastoralism if appropriately managed.

Response to climate change and variability involves the development of effective adaptation strategies to minimize the effect and maximize the available opportunities. Effective adaptation planning is however based on robust information on the trend of climate parameters especially rainfall and temperature. The results of this study show increased frequency of drought and dry spells since the year 2000, with six years (2000, 2003, 2004, 2007, 2008 and 2011) having negative Standardized Precipitation Index (SPI) values between 2000-2011 indicating low amount of rainfall in the area in those years. The increase in droughts events has adversely impacted pastoralist livelihoods, food security, human and animal health, vegetation, and child education in the study area. The study also shows increase in minimum temperature (1.41^0C) and maximum temperature (0.47^0C) between 1970 and 2013, which was confirmed by communities which reported gradual increase in daily temperature within the last thirty years. This corroborates the recent trends of global warming as reported by the latest Intergovernmental Panel on Climate Change (IPCC, 2014) report.

Climate information is a useful tool for minimizing climate risk among pastoralist communities in the ASALs of Kenya. This study shows that Pastoralist communities over the years have developed indigenous methods of predicting climate trends. They also have useful information about climatic trends and occurrence of extreme climatic events such as drought in their communities. It is therefore important to understand and appreciate the indigenous knowledge of communities about climate change and variability in planning adaptation strategies.

The increase in the frequency of dry spells and droughts over the last few decades in Kajiado County is increasing the vulnerability of Maasai pastoralists to climate change and variability. There is a direct relationship between access to basic infrastructure such as electricity and hospital, and vulnerability of households to climate change and variability. The significant influence of herd size, livestock diversity, access to credit, household size, land size and livestock mobility on the pastoral household vulnerability was also reported in this study. These factors significantly influenced the ability of the Maasai to cope during extreme climatic events. The study observed disparity in the vulnerability levels of households within the communities and also among wards in Kajiado East. Resilience interventions should therefore be location specific, targeting specific households and wards which are vulnerable.

The Maasai are already taking measures to adapt to climate extremes, especially drought. Adaptation strategies such as livestock diversification, early warning system, rain havesting and several others are being used by pastoralist to adapt to climate change and variability. However, increase in drought frequency in the last few years is reducing their resilience. Lack of basic amenities such good roads and clean water is increasing vulnerability of pastoralist in the study area to climate change. The government, non governmental organizations and private sector have a crucial role to play in enhancing adaptation and coping strategies of Maasai pastoralist to climate change and variation.

9.2 Recommendations

This study has shown that vulnerability of pastoralist households to natural shocks has been worsened by climate change and variability. Based on the results from this study, the following recommendations have been suggested:

(1) **Collaboration among stakeholders and integration of various sources of knowledge in addressing climate change and variability**: Climate change is a complex issue and transdiscplinary approach which involves integration of various sources of knowledge is needed to effectively address the impact of climate change and variability. The Maasai are well informed about their environment and they possess indigenious knowledge that will be useful for planning climate change adaptation strategies.

(2) **Efficient early warning system**: The use of available technology such as mobile phones and community radio is an effective means of disseminating climate information and seasonal forecasting among pastoralist communities in Kajiado County. Efficient early warning system endows the communities with wider range of information and enhances their ability to take decision during climate extremes.

(3) **Provision of basic amenities in rural communities in ASALs of Kenya**: The study observed a direct correlation between vulnerability and availability of basic amenities in rural areas in Kajiado County. Provision of basic amenities such as good roads, electricity, hospitals and water are no regret options that will reduce vulnerability of rural communities to climate change and variability. Climate change adaptation strategies should not be stand alone interventions; it should be embedded in broader socio-economic and developmental plan of government.

(4) **Implementation of policies and strategies that will enhance resilience of pastoralists to climate change and variability**: Government policies targeted towards enhacing resilience of pastoralist communities to climate change and variability should be implemented. The recently adopted Kenya arid and semi-

arid lands Policy if well implemented will be crutial in supporting pastoralist livelihood in ASALs. The Kenya climate change Act 2016 should be well implemented to set legal and institutional framework for climate change adaptation and mitigation in Kenya. Policy document should address the fragmentation, privatization and sale of land that is having severe impact on pastoralist livelihoods in Kajiado County.

(5) **Adaptation strategies should be location specific**: The high spatial variation in climate parameters especially rainfall in Kajiado County shows that locations and sub-counties are impacted differently by climate change and variability. Climate adaptation options that are suitable for the highlands of Ngong and Loitokitok may not be necessary be suitable for the lowlands of Magadi. Location specific interventions are therefore necessary to address the impacts of climate change in the County.

9.3 Recommendation for Future Research

There is need for further research to have a more in-depth understanding of vulnerability and adaptation of Maasai pastoralists to climate change in Kajiado County. This study suggests the following areas for future research:

(1) The impact of land fragmentation and privatization on vulnerability of pastoralists in Kajiado County

(2) The impact of rainfall variation on vegetation dynamics in pastoral lands. This includes analyzing the linkage between rainfall variation and normalized difference vegetation index (NDVI) in Kajiado County.

(3) Integrating information and communication technology with adaptation strategies being practiced by the Maasai to enhance early warning system.

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ANNEX 1

Questionnaire for household head in Kajiado County

This questionnaire will be administered to head of selected households in Kajiado County. The aim of the questionnaire is to (1) determine general household and economic characteristics (2) access the perception of Maasai to climate change and variability (3) evaluate the impact of climate change and variability on livelihood (4) describe adaptation and coping strategies of pastoralist communities and the challenges they face while adapting to climate change and variability

Questionnaire No---

Part A: Household demographics

1. Location(ward)--
2. Village--
3. Community--
4. What is the gender of household head?

   Male ( ) Female ( )
5. What is the age of the household head in years? ---------------------------------------
6. What is the level of educational level of household head?

   Informal education ( ) Primary ( ) Secondary ( ) Diploma ( ) University ( ) Others
7. What number of years has the household head lived in the area? --------------------
8. What is the size of your household? --
9. What is the marital status of the household head? -------------------------------------
10. Can you give the number of household member that falls within these age groups?

    0-10years-------------10-20years------------20-30years--------------30-40years-----------

    --------40-50years-------------50-60years----------------- 60years and above---------------
11. What are your sources of water for domestic use? (Allow multiple responses)

    Boreholes ( ), Dam ( ) water pans, rivers ( ) tap water ( ), dry river beds ( ) Any other……………………………….

Part B Socio economic characteristics

1. Number of economically active members living in household

Household members	Number of male	Number of female
Unpaid family workers		
Self-employed small scale business		
Wage employed		
Government employed		
Others specify		

2. Number of economically inactive members of the household

Household members	Number of male	Number of female
Too young		
Too old		
Sick		
Disabled		
Others specify		

3. Which of the following household assets do you have?

Asset	Please tick
Radio	
Television	
Mobile phones	

4. Which of the asset listed above do you use in obtaining information for climate change and variability? Radio ( ) Television ( ) Mobile phone ( )
5. Which of these facilities do you have access to?

facilities	Please tick
Electricity	
Toilet	
Hospital	

6. What are the sources of your family income and amount made per year

sources	Rank (1-5)	Amount/year
Livestock keeping		
Livestock trading		
Crop farming		
Tourism		
Business		
services		
Government employment		
Others (specify)		

7. Use the table below and provide an estimate of the average number of livestock you owned during the periods listed below

Livestock group		Number of livestock owned			
	Now 2014	5years ago	10years ago	15years ago	20years ago
Cow					
Goat					
Sheep					
Horse					
Carmel					
Donkey					
Poultry					
other					

8. What do you think is the reason for this variation over the years? --------------------
----

9. Use the table below and provide an estimate of amount of crop produced by you over a period listed below in Kg

Crop	Amount produced in Kg				
	Now 2014	5years ago	10years ago	15years ago	20years ago
Maize					
Sorghum					
Beans					
Cassava					
vegetables					
potatoes					
Rice					
tomatoes					
Onion					
Others					

10. What do you think is the reason for this variation over the years? --------------------
    ----

    Do you own land ( ) yes ( ) No. if yes what is the land size--------------(ha)

Part C Perception to climate variability and change

1. Do you think that rainfall in your area is changing or becoming unpredictable? ( ) Yes ( ) No
2. . If yes give reasons for your answer---

   ----
3. Do you think environmental temperature in your area is changing or becoming unpredictable? ( ) Yes ( ) No
4. If yes give reasons for your answer--

   ----

5. Explain how you predict the following climatic parameters in your area

Climatic events	Forecast signs
Rainfall	
Drought	
Late rain	
Flood	
Land slide	
Increased cold temperature	
Others specify	

6. Have you experience any of the following climate related disaster in the past 10years?

Climatic event	Experience	Frequency	Risk
Drought			
Flood			
Late rain			
Shorter rain			
Hail storm			
Increased cold temperature			
Increased hot temperature			
Others Specify			

Frequency0=never, 1=every year, 2=2-3years, 3=3-5years, 4= 5-7years, 5=7-10years.

Risk 3= High risk, 2= medium risk, 1=low risk, 0=no risk.

7. In your opinion do you think climate change and climate variability has effect on the following?

Impacts	effect
Food production and consumption	
Livestock production	
Income source	
Access to casual labour	
Education of household members	
Disease and pest in animals	
Human health	
Family asset	
Other specify	

C8 In what ways did these climatic condition affect your household activities? (Tick the appropriate and rank severity) Rank codes 3= most severe 2= severe 1= less severe 0= No effect

Activity	Drought/ Dry spell	Floods	Late rain	Short rain
Reduced/failure of crop yield				
Long distance to fetch water for domestic use				
Crop destruction				
Low pasture production				
Pest and disease infestation				
Low demand for Agric labour				
Increased price of food stuff				
Migration				
Destruction/loss of				

infrastructure				
Long distance to graze livestock				
Death of livestock				
Tribal conflict				
School dropout				
Sickness				
Loss of household member				
Others specify				

Part D Adaptation and coping strategies of households to climate change and climate variability

1. How does your household always respond to the following climatic factors?

Climatic factor	Adaptation strategies (multiple possible)
Drought	
Floods	
Late rain	
Short rain	
Dry spell	
Strong wind	
Increased hot temperature	
Others specify	

2. What are the challenges in trying to adapt to the effect of change in climate factors

Climatic factors	Challenges (multiple possible)
Drought	
Floods	
Late rain	
Short rain	
Short rain	
Increased hot temperature	
Others specify	

3. Rate the adaptation strategies below based on their level of importance.

S/N	Adaptation/coping strategy	Very important	important	Moderately important	Low importance	No importance
1	Migration					
2	Destocking					
3	Buying hay					
4	Paddock grazing					
5	Diversify livelihood					
6	Table banking and self help group					
7	Irrigated farming using borehole					
8	Selling of land					
9	Rain harvesting					
10	Sending children to school					
11	Tree planting					
12	Building dams					

13	Greenhouse farming					
14	Diversification of herds					
15	Animal health training					
16	Food aid					
17	Slaughtering of weak animals					
18	Harvesting of wild fruit					

4. What are the opportunities in coping and adapting to the effect of changes in climate factors

Climatic factors	Opportunities (multiple possible)
Drought	
Flood	
Late rain	
Short rain	
Increased hot temperature	
Heavy rain	
Others (specify)	

5. Do you have free mobility of your livestock during extreme climatic event ( ) Yes ( ) No
6. Have you ever received support or credit facilities during climate induced problem
( ) Yes ( ) No

7. If yes, indicate type of support and source

Type of support	Source	Beneficiary (1)household (2) Women (3) children	Comments appropriateness or effectiveness

8. What do you suggest could be appropriate and effective strategies for adapting to climate variability in your community?

Risk	Effective adaptation strategies	Support required
Drought		
Flood		
Late rain		
Short rain		
Increased hot temperature		
Heavy rain		
Others specify		

9. Do extension workers come to your farm? ( ) Yes ( ) No
10. Do you receive any climate information? ( ) Yes ( ) No

11. What climate information do you receive? From where and how often and receives it?

Type of information	Primary source	How often do you receive	Who receives it (1) HH head (2) women (3) children (4) everybody
Daily forecast			
Weekly forecast			
Monthly Forecast			
Seasonal Forecast			
Drought Forecast			
Others specify			

ANNEX 2

Focus Group Discussion Questions

(1) What are your sources of livelihood

(2) How do you view change in climate (rainfall and temperature) in your community

(3) Do you have indigenous ways of predicting rainfall? If yes what are the ways

(4) How often do you experience drought in your area

(5) Can you give years and local names of major drought in your area

(6) How has climate change affected your livelihoods

(7) How has climate change affected your finances

(8) How has vegetation, land use and livestock species been affected by climate change

(9) Has drought lead to the emergence of new human or animal disease in your area

Coping and adaptation strategies

(1) What coping strategies have you been using to adapt to climate change and variability

(2) What options do pastoral communities have to reduce the effect of climate change and variability

(3) What coping strategies do you think will be useful to adapt to climate change that you are not yet using either due to the cost or expertise

(4) What kind of livelihood can you diversify to that can reduce the negative effect of climate change on your household

(5) Which organizations assist your communities during drought

(6) Do you always have government assistance during drought? If yes, how do they assist

(7) What do you think government can do more to reduce the effect of climate change and variability

(8) What role does NGOs play during drought?

(9) If we want to assist the community to adapt to climate change and variability, what do you think are the most important priority now

ANNEX 3

Vulnerability index of Maasai communities in Kajiado East sub-County

Vulnerability index of Maasai communities in Kajiado East sub-County			
Villages	Vulnerability index	X-Coordinate	Y-Coordinate
Kisaju	2.156	36.82	-1.6
Isinya	-0.37	36.846905	-1.686137
Olmerui	2.146	36.880001	-1.75
Poka	-0.305	37.450001	-2.13
Sultan	-0.211	37.369999	-2.02
Kitengela	0.364	36.959473	-1.47332
Konza	-1.805	37.130276	-1.74394
Mashuru	0.731	37.130136	-2.100736
Oletepes	0	36.77	-1.47
Olooloitikoshi	0.484	36.799399	-1.565057
Oloosirikon	-2.215	36.814567	-1.429823
Sholinke	-0.191	36.780431	-1.511096
Iltepes	0.225	37.22733	-2.188374
Kenyewa	1.436	37.576867	-2.192087
Kibini	0.44	37.287742	-2.128381
Arroi	0.084	37.295171	-2.024299
Imaroro	-1.332	37.093964	-1.947899
Mbilini	1.68	37.049999	-1.97
Ilkiushin	-0.313	36.944813	-1.750651
Enkirigirri	0.295	36.854771	-1.780559
Ilpolosat	-2.307	37.057809	-1.750804
Olkinos	-1.151	36.881006	-1.664846
Olekaitoriori	0.31	37.168069	-1.99924
Oloibor Ajijik	0.741	37.063559	-1.892305
Wulu	0.868	37.138513	-1.80965
Esilanke	2.227	36.760193	-1.716342
Olgulului	1.017	37.301546	-2.229515
Noompaai	-1.151	37.461046	-2.341064
Kekayaya	4.021	36.743001	-1.593895
Lenihani	-2.049	37.056348	-1.688547
Embakasi	0.057	36.83022	-1.389628
Kware	-0.106	36.811033	-1.45567
Enkutoto mbaa	0.021	36.741794	-1.434757
Kepiro	3.468	36.851453	-1.638716
Korrompoi	-0.368	36.915394	-1.621721
Olturoto	-1.509	36.900053	-1.64196
Naserian	0.434	36.966653	-1.656838
Emampariswai	0.487	36.982271	-1.695545
Ntipilikuani	0.02	36.669991	-1.691833
Olepolos	1.539	36.702385	-1.507252
Oloshaiki	-1.53	36.952704	-1.563884
Ormoyi	2.812	36.732128	-1.651733
Enkasiti	-0.137	36.866739	-1.573125
Mbuni	-0.441	36.871232	-1.551958