CLIMATE VARIABILITY, LAND-USE AND LIVELIHOODS IN KIBOKO-KIBWEZI OBSERVATORY, KENYA

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THE INFLUENCE OF CLIMATE VARIABILITY AND CHANGE ON LAND-USE AND LIVELIHOODS IN KENYA'S SOUTHERN RANGELANDS

By

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DECLARATION AND APPROVAL

I hereby declare that this thesis titled "**The Influence of Climate Variability and Change on Land-use and Livelihoods in Kenya's Southern Rangelands"** is my original work and has never been presented for a degree in any other university.

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DEDICATION

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ABBREVIATIONS AND ACRONYMS

asl	Above Sea Level
AAME	Active Adult Male Equivalents
AE	Adult Equivalents
AEZ	Agro-Ecological Zone
AMCEN	African Ministerial Conference on Environment
ASALs	Arid and Semi-Arid Lands
CBS	Central Bureau of Statistics
COF	Climate Outlook Forum
DJF	December, January and February
EAMD	East African Meteorological Department
ENSO	El Nino-Southern Oscillation
FAO	Food and Agriculture Organisation
FAOSTAT	Food and Agriculture Organisation Statistical Database
FGD	Focus Group Discussions
FGLS	Feasible Generalised Least Squares
FPI	Food poverty index
GCM	Global Circulation Model
GCOS	Global Climate Observation Systems
GDP	Gross Domestic Product
GHG	Greenhouse Gas Emissions
GIS	Geographic Information System
GLS	Generalised Least Squares
GNB	Good News Bible
GOK	Government of Kenya
GPS	Global Positioning System
HDI	Human Development Index
HIV/AIDS	Human Immunodeficiency Virus / Acquired Immunodeficiency Syndrome
ICPAC	IGAD Climate Prediction and Application Centre
IFPRI	International Food Policy Research
IGAD	Intergovernmental Development Authority
ILO	International Labour Organisation

IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter Tropical Convergence Zone
KEFRI	Kenya Forestry Research Institute
KIHBS	Kenya Integrated Household Budget Survey
KMD	Kenya Meteorological Department
MDGs	Millennium Development Goals
NEPAD	New Partnership for Africa's Development
OLS	Ordinary Least Squares
OSS	*Observatoire du Sahara et du Sahel*
PRA	Participatory Rural Appraisal
RCM	Regional Circulation Models
ROK	Republic of Kenya
SEI	Stockholm Environment Institute
SEM	Simultaneous Equation Model
SLM	Sustainable Livelihood Model
SPSS	Statistical Package for Social Scientists
SSA	Sub-Saharan Africa
TLU	Tropical Livestock Unit
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USDA	United States Department of Agriculture
VFI	Vulnerability to Food Insecurity
WFP	World Food Programme
WLS	Weighted Least Squares
WWF	World Wide Fund for Nature

ABSTRACT

Climate variability and change are major challenges in ensuring household food security. However, there is a dearth of knowledge and information on the interactions between climate variability, land-use and household vulnerability to food insecurity. In this study, food insecurity was used as a proxy for livelihood. This study was conducted in Makueni and Kajiado Counties, within the southern rangelands of Kenya, to address this gap. The main objective of the study was to establish the influence of climate variability and change on household food security under different land-use systems in the two selected counties. Data sources included household interviews, Focus Group Discussions, direct observations, Key Informant interviews and secondary data.

Data were analysed using both descriptive statistics and regressions. Descriptive statistics suggested that among other factors, there was a link between rainfall and household vulnerability to food insecurity (VFI). Also, households in Makueni County, predominantly agropastoral, were more food secure, with a VFI of 0.27, than those of Kajiado County, which had a VFI of 0.59. Pastoral households had low access to resources such as climate information, education and income, making them more vulnerable to food insecurity than their agropastoral counterparts.

From the descriptive statistics, it was difficult to gauge the influence of various variables on vulnerability to food insecurity. As a result, regressions were carried out. A simultaneous equation model (SEM), estimated through a two-stage least squares approach, was applied to establish the determinants of household vulnerability to food insecurity. The SEM estimation showed that both socio-economic and climate factors influence household VFI. The variables that were found to have a positive and significant influence at $p \leq 0.05$ include land size, household size and rainfall for Makueni County, and gender of the household head, access to climate information and off-farm activities for Kajiado County. This implies that, for Makueni County, households with large land holdings, large household sizes and higher rainfall are less vulnerable to food insecurity. Similarly, for Kajiado County, female household headship, off-farm opportunities and access to climate information are fundamental to reducing household vulnerability to food insecurity. Moreover, herd size was shown to influence VFI in both counties, with a negative and significant influence at $p \leq 0.05$. Thus, due to diminishing grazing resources, large herd sizes have shown to increase VFI.

A regression model using time series data was estimated to capture the temporal aspects of climate that would otherwise not be captured by descriptive statistics and the SEM. Data for Kajiado and Makueni Counties for a period of 31 years were used to establish inter-temporal effects of climate and non-climate related parameters on household VFI. Descriptive statistics on the data set suggested that climate variability (rainfall), livestock offtake, maize production, stocking rate, and beef and maize prices influence household food security. GLS regression results established that livestock offtake had a positive and significant influence ($p \leq 0.05$) on household security for both counties. In Kajiado County, rainfall, mean annual temperature and maize price were significant at ($p \leq 0.05$). For Makueni County, beef price and stocking rate significantly ($p \leq 0.05$) influenced household food security.

From the results of this study, government policies for Kajiado and Makueni Counties need to promote improved livestock breeds as a means of destocking and enhancing livestock performance. In Kajiado County, access to climate information, creating micro-industries, targeting women based organisations, and promoting micro-climates through agroforestry and reforestation would improve livelihoods and reduce household VFI. Similarly, for the agropastoral households in Makueni County, promoting agroforestry and reforestation programmes, facilitating access to land, maintaining correct stocking rate, improving beef prices through improved marketing and managing household sizes would lead to reduced VFI.

CHAPTER ONE

INTRODUCTION

1.1 SUMMARY

This chapter puts the study into context. It provides background information, the research problem, justification and objectives. It further presents hypotheses, limitations for conducting this study and a brief description of the thesis structure. The chapter has introduced a brief description on how climate variability and change may impact differently on various land-use practices. Most of the studies on climate variability and change, land-use and livelihoods consider various land-use systems in isolation. Furthermore, most of these studies on climate variability and livelihoods are purely qualitative. Thus, this chapter further sheds light on the relevance of considering land production systems in the arid and semi-arid lands as a unit, when addressing development challenges such as food insecurity in the context of changing climate and land-use patterns.

1.2 BACKGROUND

The full weight of scientific evidence suggests that climate is changing and becoming more variable due to human activities; and that future changes will have significant impacts on natural and human systems (IPCC, 2007). Africa is the most vulnerable to the impacts of climate variability and change due to its low adaptive capacity attributed to the deteriorating ecological base, widespread poverty, inequitable land distribution, and high dependence on natural resources (Thornton *et al.*, 2006; ROK, 2009). Moreover, the continent's key sectors of economic growth such as agriculture are the worst hit by the impacts of climate variability and change. In sub-Saharan Africa, agriculture contributes 30 per cent to the gross domestic product (GDP), with over 90 per cent of the rural population depending on rain-fed agriculture for income and food. In East Africa, the sector contributes 40 per cent of the GDP and provides livelihoods to about 80 per cent of the region's population (IFPRI, 2004). Similarly for Kenya, approximately 75 per cent of its population depend on rain-fed agriculture for subsistence, and the agricultural sector contributes 30 per cent to GDP and accounts for 80 per cent of the national employment, mainly in the rural areas (ROK, 2010).

Hence, variations in climate in terms of rainfall distribution and timing have great threats on the well-being of households and the national economy at large.

Kenya has identified its ASALs as the most vulnerable areas to climate-related risks with huge impacts on livestock, small-holder agriculture and tourism, which are the dominant sources of livelihoods in these areas. The greatest challenge to rain-fed farming in the ASALs is dealing with the variability of rainfall both within and between seasons. This often leads to economic and food security risks countrywide with a greater impact on populations whose livelihoods are dependent on agriculture and other related natural resources. Scientific evidence shows that climate variability and change are expected to further exacerbate the variability in rainfall and temperatures (IPCC, 2001; Thornton *et al.,* 2006; IPCC, 2007). Moreover, future climate projections show a substantial increase (of up to 5°C) in the annual average temperature for Kenya by the end of the century. This could lead to a decrease in cattle numbers by the year 2050, an initial increase in sheep and goat population by 2030, and a decrease by 2050 (Orindi *et al.*, 2006).

Given the dependence of Kenya on natural resources, and especially agriculture, it is beyond doubt that the impacts of climate variability and change have introduced a new dimension to the national fights against food insecurity and poverty. Studies have indicated that fluctuations and variations in climate, particularly rainfall and temperature, adversely affect the physical, biological and socio-economic systems leading to disasters and calamities (Tasokwa, 2011). For example, the number of people affected by drought in the country has increased tremendously from 46,000 in the 1970s to 7.8 million in 2000s (Orindi *et al.,* 2006).

As climate variability and change continue to be more unpredictable, land, a key production asset in the ASALs, is also becoming of great concern. Historically, the land in the ASALs of Kenya was owned communally with pastoralism as the main production system. This production system capitalised on mobility and herd diversification as the key strategy to utilise the sparse dryland resources (Nyariki *et al.,* 2002; Amwata, 2004; Sunya, 2003; Wasonga *et al.,* 2010). However, population increases, liberation of markets, and land reforms have favoured privatisation and fragmentation of some of these lands, leading to increased sales of land to ‘immigrants’ including those from farming communities, thus facilitating the conversion of these fragile ecosystems to unsustainable land-use (Amwata, 2004; Wasonga *et al.,* 2010). As more pastoralists convert to agropastoralists and even pure farming, climate continues to be more and more varied resulting in recurrent extreme climate events such as famines and drought, further increases vulnerability of rural livelihoods to climate risks. One of the contributing factors is inadequate knowledge and information on the role of climate and non-climatic factors on land-use and household food security. Studies have shown that climate information has the potential of increasing resilience and reducing the susceptibility of households by facilitating proactiveness to maximise opportunities available while minimising the impacts of extreme weather events such as droughts and floods (Ziervogel, 2004). In most cases, information is inaccessible; and if it does, it is neither timely nor packaged in a form that is helpful to the end users.

The role of climate information has been discussed in the agricultural sector (Ziervogel, 2004). However, its role in other forms of land-use has not been fully deliberated upon. Many studies overlook the fact that in the ASALs, different production systems such as agriculture, forestry, pastoralism and tourism are interrelated and coexist as a unit. Besides, they all contribute to the gross domestic product; hence they are very significant to the national and local economies. For example, more than 75 per cent of Kenya is ASALs, hosting over 60 per cent and 75 per cent of the country's livestock and wildlife respectively, with the former accounting for 26 per cent of total national agricultural production (Ngugi and Nyariki, 2005; Orindi *et al.,* 2006).

Therefore, if deliberate attention is not directed at managing the impacts of climate variability and change in the context of changing land-use patterns, the majority of rural households especially in the ASALs will face serious insecurity in food and incomes, leading to declining agricultural production and reduced assets, consequently jeopardising the well-being of the households. All these would subsequently lead to further degradation of the environment and natural resources, thereby undermining the efforts of poverty reduction, sustainable development and the attainment of other Millennium Development Goals (MDGs).

Thus, embracing a systems approach is fundamental in the ASALs given the overlaps among different land production systems that coexist by complementing, supplementing and competing against each other. For that reason, the integration of climate and non-climate related aspects into the development of rural households as well as national strategies are vital if meaningful development has to be gained in the ASALs. This should ensure holistic understanding of the evolution of the impacts of climate variability and change, their implications on rural households and the capability of the households to cope with these multiple stresses over time.

1.3 PROBLEM STATEMENT

Rural livelihoods are frequently subjected to multiple shocks and stresses that are likely to increase household vulnerability. The negative impacts associated with climate variability and change are further compounded by many other factors, including widespread poverty, human diseases, and high population density, the last estimated to double the demand for food, water and forage within the next 37 years (WWF, 2006). Climate variability and change are some of the pervasive stresses that individuals and communities in the rural areas have to cope with and adapt to. For many decades, households and communities have developed ingenious ways of adapting to varying degrees of extreme weather events. Not all have shown remarkable successes, however, and climate science, especially in terms of the seasonal forecast, has provided an indication of how to analyse rainfall trends over years, and has thus been considered a tool that could help prepare for and/or adapt to climate variability and change (Ziervogel and Calder, 2003).

In this regard, skills in climate forecasting allow for the prediction of future anticipated climate-related events, thus offering considerable opportunities to the managers of agricultural systems and other land-users to realise the systems' potential through increased productivity and profitability, reduced risks, and better policies for improved food security. However, these opportunities have not been fully tapped due to a limited understanding of probabilistic information, difficulty in communicating risk and probability (Ziervogel, 2004) and the consideration of land-use systems in isolation. These have been further exacerbated by poor packaging of the information without due consideration of the needs and priorities of end-users under different land-use systems. In some cases, emphasis is made to a single land-use system without considering other land-uses, yet they coexist as a unit. Therefore, to achieve more meaningful results, it is critical that various land-use practices in the ASALs be understood as a unit. To bridge this gap, understanding the evolution of the impacts of climate variability and change, their implications on adaptation strategies for specific land-use systems is central. This would facilitate a shift from passive acceptance of climate variability and related impacts to proactive adaptation strategies. This study contributes to the previous attempts by analysing the innovative approaches for integrating local knowledge and science in managing climate risks by focussing on a more holistic approach of a 'system'. This takes into consideration all land production systems in the study area as a unit without bias towards specific sub-sectors of agriculture as has been in the previous studies.

1.4 JUSTIFICATION

Climate variability and change introduces additional uncertainty in sustainable land management. Shifts in seasonal characteristics, such as alternating wet and dry conditions together with their associated effects, place an additional strain on human health, food security, water availability and viability of rural livelihoods in the ASALs. It is apparent that in the Kenyan ASALs, climate and livelihoods are linked and a majority of the country's population are heavily dependent on rainfall for the various land-use practices. As a result rural livelihoods and food security are highly vulnerable to climate variability especially with respect to shifts in growing conditions or seasonality (WWF, 2006). Studies on rural livelihoods in the ASALs have focussed more on socio-economic aspects (Nyariki and Wiggins, 1997, 1999; Ngugi and Nyariki, 2005; Sunya, 2003; Amwata, 2004) and others on biophysical aspects of climate (Liverman, 1990; Hewitt, 1995; Pulwarty and Riebsame, 1997; Füssel, 2007), but less on their integration.

So far, there is limited research on the systems approach to understanding the interactions among climate variability and change, land-use types and livelihoods in the ASALs of Kenya. Most studies are descriptive and focus on measurement of indices of vulnerability at the national and regional levels (Thornton *et al.,* 2006; Downing, 1992) while some have profiled determinants of vulnerability at household level (Adger *et al.*, 2004). However, none of these studies has attempted to analyse the interplay between various factors such as climate, land-use and livelihoods. Studies carried out by Orindi *et al.* (2006) have emphasised on drought and pastoralism, ignoring other land production systems, which coexist in the same settings while equally contributing to the GDP and job creation at the local and national scales. In the ASALs, livelihoods and land production systems coexist as a unit, and this understanding often lacks in many studies.

Studies almost similar to the current one have been done in Lesotho and Malawi (Ziervogel and Calder, 2003; Ziervogel, 2004; Tasokwa, 2011) but due to geographical differences, cultural settings and economic endowment, the recommendations may not be applicable to Kenya's ASALs. The current study contributes to the understanding of the influence of climate variability and change on land-use options and their interrelations to livelihoods in the ASALs from a systems point of view. This approach is crucial to establishing the adaptation strategies that have positive overlaps in various land-use options to be built upon and the externalities to be minimised.

1.5 OBJECTIVES

The overall objective of this study was to establish the influence of climate variability and change on land-use and livelihood adaptation strategies in the southern rangelands of Kenya. The specific objectives were to:

1. Establish the occurrence of extreme climate events and the existing coping strategies under different land-use systems.
2. Establish the biophysical and socio-economic factors influencing household vulnerability to food insecurity under different land-use systems.
3. Establish and document the existing methods used under different land-use systems to forecast climate.
4. Compare the household vulnerability to food insecurity under different land-use systems.

1.6 RESEARCH HYPOTHESES

This study was guided by three hypotheses, namely:

1. The existing coping and adaptation strategies do not vary with land-use systems in the study area.
2. The biophysical and socio-economic factors influencing household vulnerability to food insecurity differ between Kajiado and Makueni Counties because of differences in agroecological potentials.
3. Different methods exist for climate forecasts in different land-use systems.

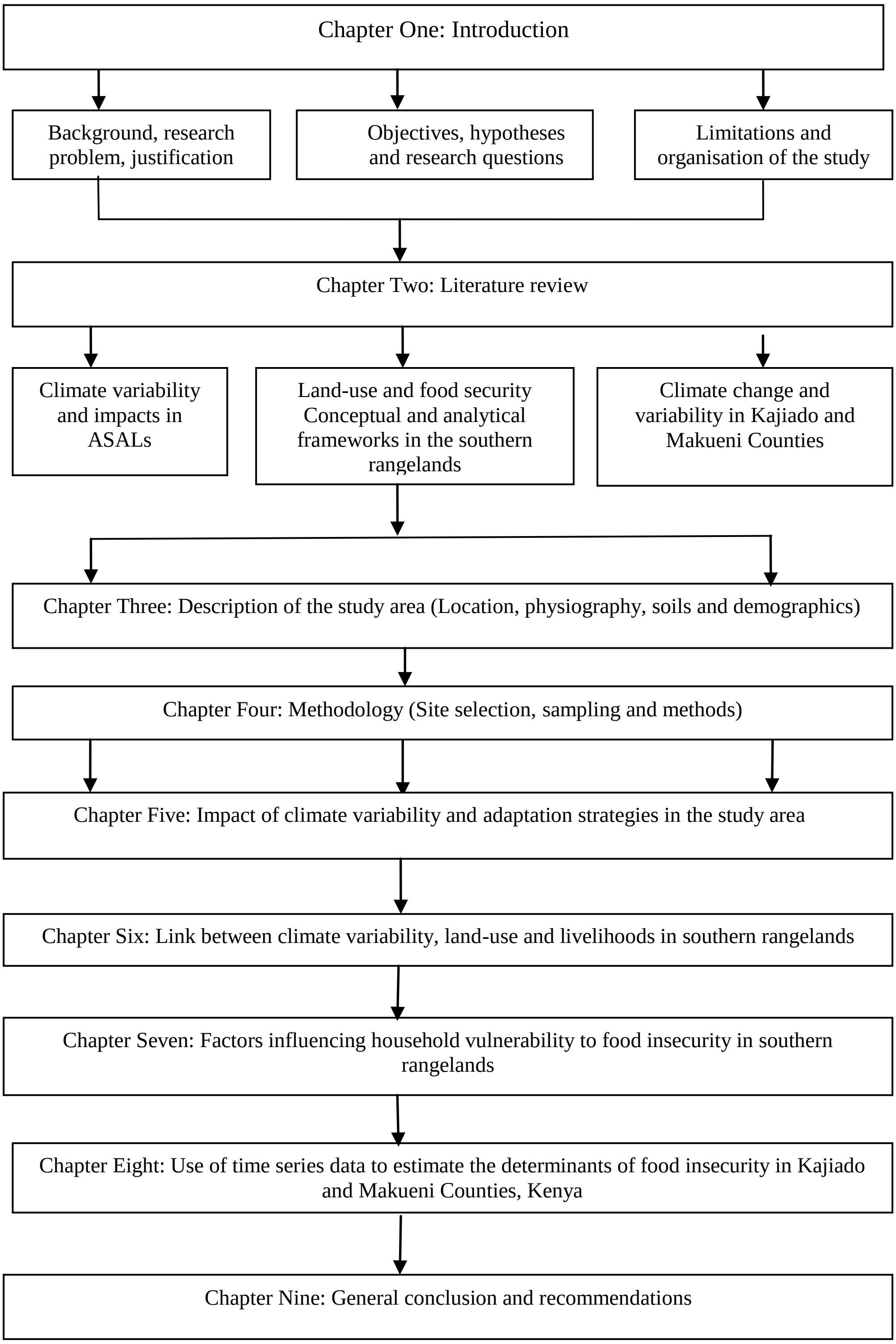
1.7 CHALLENGES ENCOUTERERED DURING THE STUDY

Data availability was a major challenge. Getting consistent data on the selected variables on a yearly basis for a period of 31 years was difficult. Thus, interpolations using series means were used in some cases. However, this did not have a major effect on the study outcome since there were few data gaps. Also, the local communities were reluctant to participate in the study due to the fact that many studies had been carried out in the same area in the past with no feedback. In addition, at the time of the study, the two counties were experiencing drought and several households had moved with livestock to distant areas in search of pasture and water. Thus, many visits were made to ensure that all the households selected were interviewed. As a result, the administration of questionnaires took more time than planned.

1.8 ORGANISATION OF THE STUDY

This study is presented in nine chapters as shown in the thesis plan (Figure 1.1). Chapter One presents the general background to the study. Also, this chapter defines climate variability and change, food security, land-use and the links between them introduced. It further presents the research problem under investigation, justification, objectives, hypotheses and organisation of the study. Chapter Two reviews literature related to climate variability and change, land-use and food security in Kenya including the arid and semi-arid lands (ASALs). The description of the study area, namely Kajiado and Makueni Counties including the study sites are presented in Chapter Three. Chapter Four discusses the general methodology used to collect data to achieve study objectives. Chapter Five describes the impacts of climate variability and change, and the existing adaptation options under various land-use systems. The link between climate variability, land-use and livelihoods are presented in Chapter Six. Further, Chapter Seven identifies and quantifies the contribution of the various factors to household vulnerability to food insecurity using a simultaneous equation model. Chapter Eight goes further to integrate climate and non-climate factors using time series data to estimate the determinants of food security. Lastly, Chapter Nine summarises the findings of the study and provides conclusion, recommendations based on the main findings of the study.

Figure 1.1: Thesis plan



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CHAPTER TWO

LITERATURE REVIEW

2.1 SUMMARY

This chapter presents literature on climate variability and change, land-use and household food security. The chapter begins with definition of concepts and terminologies used in climate variability and change, land-use, vulnerability, adaptation, adaptive capacity, resilience, household food security among others. These are followed by a review of studies on climate variability and change and their impacts on land-use and livelihoods in Africa and, Kenya, in particular. The chapter further discusses the links between climate variability and change, food security and land-use in Kenya. Finally, it reviews the methodologies and findings in food security studies in order to identify the gaps to be addressed by the current study.

2.2 DEFINITION OF KEY CONCEPTS

The definitions of some terms, such as vulnerability and risk, vary among disciplines and contexts. In these cases, broad definitions of commonly used terms are provided along with alternative definitions where applicable (ROK, 2012; IPCC, 2007; 2001) as shown below.

Adaptation: This is the process by which strategies to moderate, cope with, and take advantage of the consequences of climate events are enhanced, developed and implemented.

Adaptive capacity: This refers to the ability of a system to adjust its characteristics or behaviour in order to expand its coping range under existing climate variability or future - climatic conditions.

Coping range: This is the range of climates where the outcomes are beneficial or negative but tolerable. Beyond the coping range, the damages or losses are no longer tolerable and a society is said to be vulnerable.

Land-use: This may be defined as the way people use the land resource, which is the effect of an integrated set of biophysical and socio-economical factors (Verburg and Chen, 2000). In this study, land-use refers to agropastoralism and transhumance that are the fundamental land-use types in the study area.

Land-use change: This takes place when the use of land is altered, partly or totally over a given period of time. The change can be both caused and effected by environmental or socio-economic factors (Krausmann *et al.,* 2003).

Resilience: This refers to the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning and its capacity for self-organisation and to adapt to stress and change.

Risk: This refers to the interaction of physically defined hazards with the properties of the exposed systems, i.e. sensitivity or vulnerability. Risk can also be from the combination of an event, its likelihood and its consequences. Risk equals the probability of climate hazard multiplied by a given system's vulnerability.

Scenario: This refers to a plausible and often simplified description of how the future may develop based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from projections, but are often based on additional information from other sources, sometimes combined with a narrative storyline.

Socio-economic vulnerability: This is an aggregate measure of human welfare that integrates environmental, social, economic and political exposure to a range of harmful perturbations.

Stakeholders: This is defined as those people who have interest in a particular decision, either as individuals or as representatives of a group. This includes people who influence a decision as well as those affected by it.

Vulnerability: This is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. In this study, vulnerability is taken to mean the degree to which a unit is susceptible to harm due to exposure to a perturbation or stress, and the ability of the exposure unit to cope, recover or fundamentally adapt (Thornton *et al.,* 2006).

2.3 UNDERSTANDING CLIMATE VARIABILITY AND CHANGE

There are no agreed upon definitions for climate variability and climate change. The definitions of these two terminologies have evolved over time. The World Meteorological Organisation (WMO) refers to climate change as long term changes in average weather conditions (WMO, 1992) while Global Climate Observation Systems (GCOS) defines it as all changes in climate system including the drivers of changes, the changes themselves and their effects (GCOS, 1992). To the UNFCCC (1992) it means a change of 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. According to the IPCC (2007), climate change is defined as any change in climate over time, whether due to natural variability or human activity. All these definitions have mentioned natural and human causes either singly or in combination. Therefore, the current study adopts the definition by IPCC (2007) that attributes climate change to either natural variability or anthropogenic factors.

Climate variability refers to variations in the mean state and other statistics (such as standard deviations) of the climate on all temporal and spatial scales (IPCC, 2001). It captures year to year variations of climatic elements such as temperature and rainfall at several time scales (Tasokwa, 2011; Wasonga *et al.*, 2010). Variability includes more than individual weather events and may result from natural internal processes within the climate system (internal variability) or to variations in natural or anthropogenic external forces (external variability (Tasokwa, 2011). Climate is naturally dynamic (UNFCCC, 1992) and varies in space and time. 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 usually centuries. Climate variability is short-term fluctuations happening from year to year. In this study, both definitions will be used.

Climate change as the conceptual global change that is taking place and climate variability as the process taking place in the Southern Rangelands of Kenya within the time-frame of 1980s to the present were considered in the current study. The underlying concept is that global climate change causes local scale impacts and that it is not possible to treat variability separately from climate change (Smit *et al.,* 2000). The data that were used and the time-frame considered only accounted for a change over a few decades (31 years), and could therefore well be variability or a phase of an oscillation (Hagebuck *et al.,* 2005). The focus of the current study was the adaptation of rural households to change, so it is not important if the change is caused by greenhouse-gas induced global warming or local natural variability.

2.4 OVERVIEW OF GLOBAL CLIMATE VARIABILITY AND CHANGE

Climate variability and change have gained momentum across all levels over the past two decades (Tasokwa, 2011; Wasonga *et al.,* 2010; IPCC, 2007; Stern, 2006; 2006; IPCC, 2001; Adger, 2000,). Currently, there is scientific evidence on the existence of climate variability and change (IPCC, 2007; IPCC, 2001). The evidence is noted by the increase of carbon dioxide (CO_2) in the atmosphere (IPCC, 2007). Literature shows that on average global surface temperature has warmed by 0.8°C in the past century; and 0.6°C in the last three decades (Hansen *et al.,* 2003), majorly due to human activities (IPCC, 2007; 2001; Thornton *et al.,* 2006). IPCC projects that if greenhouse gas emissions, which are the major cause of climate variability and change, continue to rise, the mean global temperatures will increase by between 1.4 to 5.8°C by the end of the 21^{st} Century, consequently doubling the CO_2 concentration in the atmosphere (IPCC, 2007). As a result, future impacts of climate variability and change are projected to worsen as the temperature continues to rise and precipitation becomes more unpredictable in amount and distribution (WWF, 2006; Houghton *et al.,* 1996).

Climate variability and change impacts have the potential to undermine and even, undo progress made in improving the socio-economic well-being of many of the countries globally. It is estimated that in the coming few decades, one to two per cent of the global Gross Domestic Product (GDP) is at stake with some sectors being more exposed than others. The negative impacts associated with climate variability and change are also compounded by many other factors, including widespread poverty, human diseases and high population density, which are estimated to double the demand for food, water and livestock forage within the next 30 years (Stern, 2006).

2.5 CLIMATE VARIABILITY AND CHANGE IN AFRICA

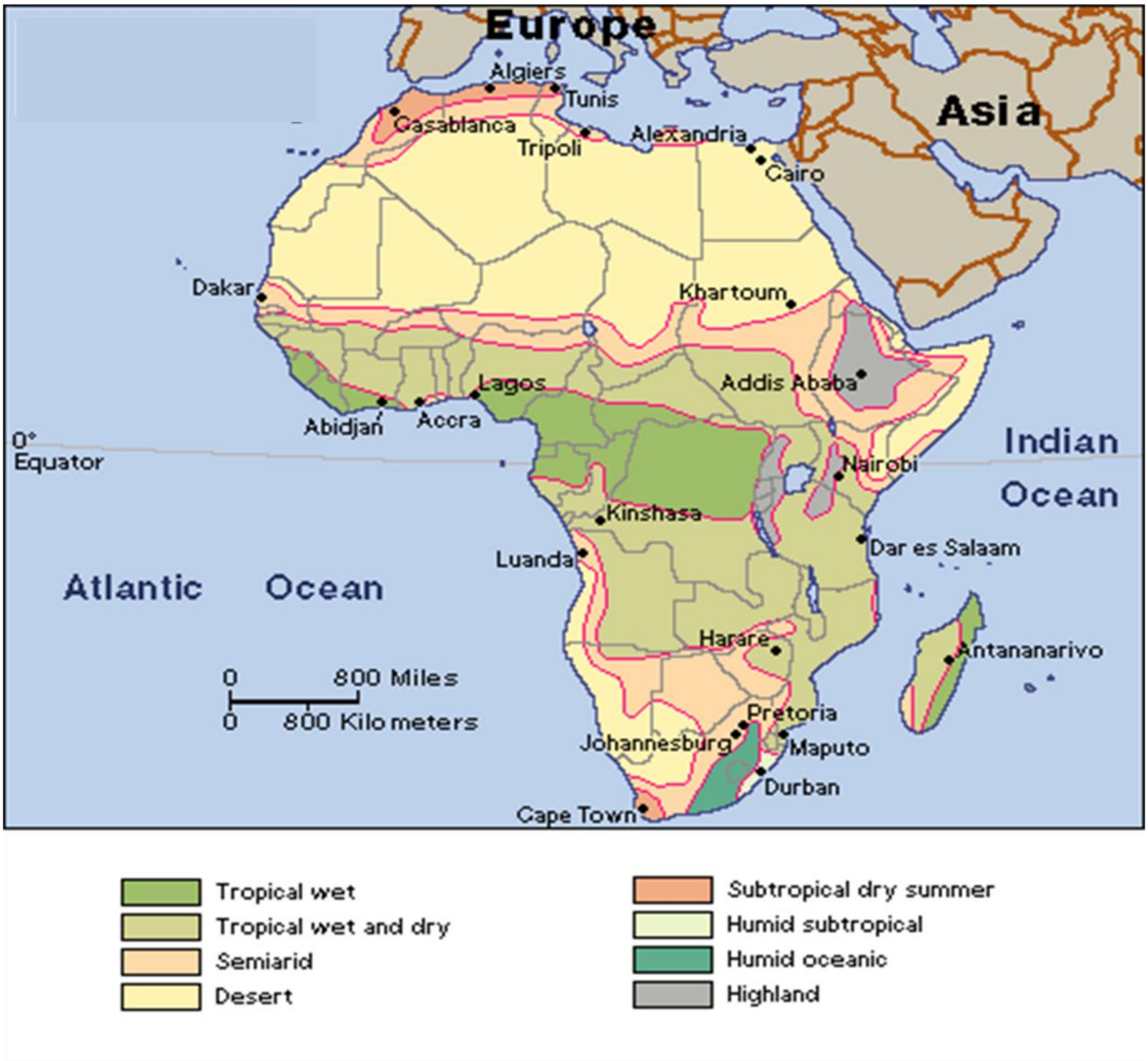
2.5.1 The Climate of Africa

Africa has the largest tropical area of all the world's continents. The distribution of African climate by region is shown in Figure 2.1. The equator runs through the middle of Africa, and about 90 per cent of the continent lies within the tropics. In this continent, climate is determined by three main drivers: the Inter Tropical Convergence Zone (ITCZ), the *El Nino-Southern Oscillation* (ENSO) and the West African Monsoon. Most of the continent has a warm or hot climate, but the humidity and amount of rainfall vary dramatically from area to area. For countries located south of the equator, the seasons are opposite those of countries that lie north of the equator. But temperatures are high all year round almost everywhere in Africa (World Book, 2009). In general, the drier subtropical regions warm more than the moister tropics.

2.5.2 Trends in Climate Variability and Change in Africa

The historical climate record for Africa shows warming of approximately 0.7°C over most of the continent during the twentieth century; a decrease in rainfall over large proportions of the Sahel, which is a semi-arid region of Sahara; and increase in rainfall in the south east Africa. Over the next century, this warming trend, and changes in precipitation patterns are expected to continue and will be accompanied by a rise in the sea level coupled with extreme weather events (Thornton *et al.,* 2006). As an illustration, the mean surface temperature in Africa has increased by only 0.5ºC since 1900, and it is anticipated that it could further increase by between 2 to 6ºC by 2100 (Hulme *et al.*, 2001; Thornton *et al.,* 2006). Moreover, projections on rainfall trends show that there will be a decrease of up to 20 per cent in North Africa, but with a general increase in equatorial areas, particularly in the east Sahel (Hulme *et al.,* 2001). The consequence is decreased soil infiltration, increased surface run-off and ultimately decreased groundwater recharge (Feddema and Freire, 2001). The trends in Africa's mean annual temperatures and rainfall for the last century are shown in Figures 2.2 and 2.3 respectively.

Figure 2.1: The Climate of Africa



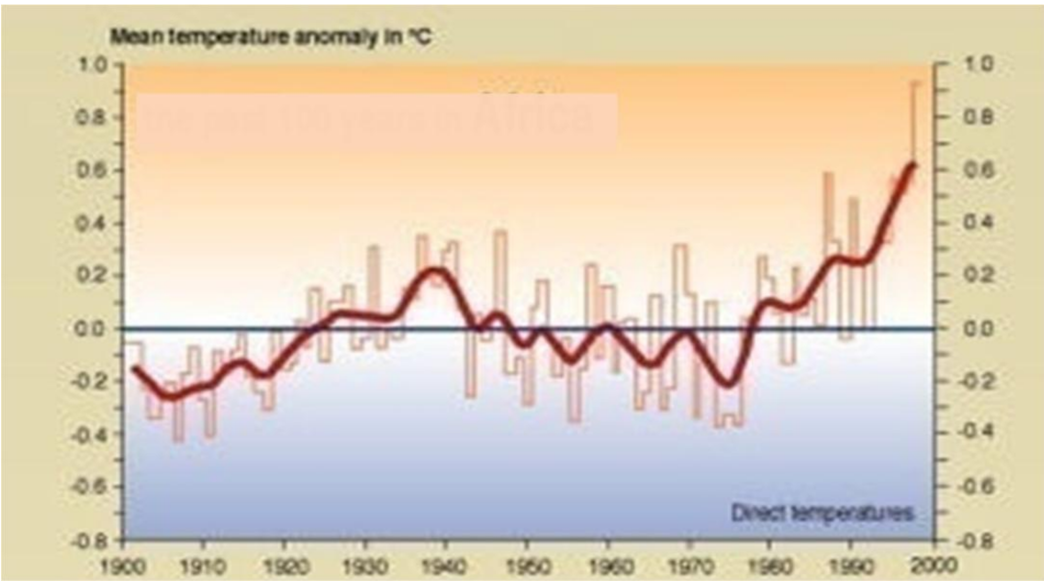
Source: World Book (2009).

The future climate change in Africa presents a great challenge. There is inconsistency in prediction of distribution of future climate changes due to incomplete understanding of the climate system and its inherent unpredictability. While this distribution is unknown, sensible guesses can be made as a reflection of its magnitude and shape, and the choices that can be made so as to sample a reasonable part of its range (Hulme *et al.*, 2001; Thornton *et al.*, 2006). Climate variability and change are manifested in four ways: slow changes in mean climatic conditions; increased inter annual and seasonal variability; increased frequency of extreme events; and rapid climate changes causing catastrophic shifts in ecosystems. The impacts of climate variability and change have implication on key sensitive sectors such as water resources, food security, health and agriculture. In these sectors, it influences precipitation and insulation, length of the growing seasons, water availability, carbon uptake, incidences of extreme weather events, changes in flood risks, desertification, and distribution and prevalence of human diseases and plant pests (IPCC, 2001).

The impacts of climate variability and change are discussed below.

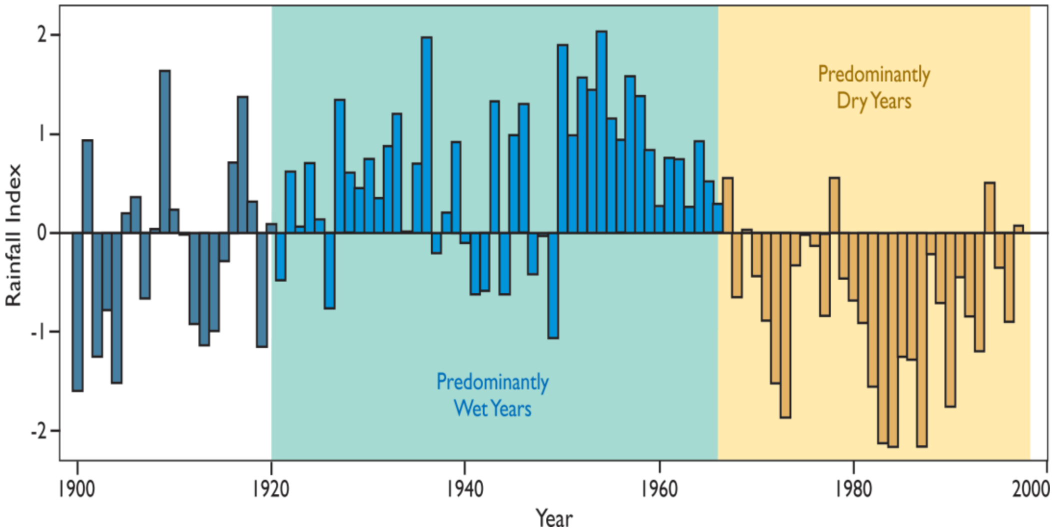
a) Floods have devastating impacts on livelihoods by destroying agricultural crops, disrupting electricity supply and demolishing infrastructure (homes, roads and bridges) (UNEP, 2005). For example, flooding in Limpopo, Save and Zambezi Valley of Mozambique claimed 700 lives, more than 250,000 displaced and infrastructure destroyed; the total cost of damage and relief work cost was about 25 per cent of Mozambique's GDP (Nkomo *et al.,* 2006). Similarly, in Kenya in 1998, 600 people were killed and 50,000 forced to flee their homes due to *El Niño* floods, costing the country about USD 1 billion (SEI, 2009).
b) Drought is a naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems. Approximately one third of African people live in drought prone areas and that about 220 million people are exposed to drought annually. The duration of drought characterises its hazard level, since it develops slowly and may last over a period of many years. The Sahel is more prone to drought and has been affected since 1960s.

Figure 2.2: Annual mean temperature anomalies in Africa (1900-2000)



Source: Nkomo *et al.* (2006); Adger and Brooks (2003).

Figure 2.3: Rainfall regimes in Africa (1900-2000)



Source: AMCEN (2010).

c) Dust and sand storms are a common phenomenon in the Sahel and Sahara region. The Sahara is the world's largest source of airborne mineral dust. It can be transported to large distances, traversing North Africa and adjacent regions and to be deposited in Europe, western Asia and America (Moulin *et al.*, 1997). Also, *haboob* in northern Sudan moves like a thick wall several hundred meters away carrying sand and dust. The frequency of occurrence of dust storms in the Sahel has increased due to overgrazing and deforestation, making the Sahel a significant source of dust than the Sahara (N'Tchayi *et al.*, 1997). The dust storms erode fertile soils, uproot young plants, bury water canals, houses and property and cause respiratory problems. On the other hand, areas where the storms have deposited the eroded soils form rich fertile soils for plant growth.

As a result of these impacts, natural and human ecosystems are forced to adjust and accommodate these changes without alteration. Failure to adjust and cope with the hazards makes the systems become more susceptible due to reduced coping capacity. Hence increased vulnerability transforms into disasters. For instance, bridges and buildings in developed countries are designed with a safety factor to withstand at least 100 year event while in developing countries of Africa, the design standards are much lower or not enforced at all. The structural preparedness gives developed countries comparative advantage especially with extreme weather events such as flooding.

Africa contributes least to the causes of climate variability and change, yet it is the worst hit by the negative impacts of climate variability and change (Tasokwa, 2011; IPCC, 2007; Jones and Thornton, 2003; IPCC, 2001). This is because of Africa's low economic development and inadequate institutional capacity (IPCC, 2001). Beides, the negative impacts associated with climate variability and change are also compounded by many factors, including widespread poverty, human diseases, and high population density, which is estimated to double the demand for food, water, and livestock forage within the next 30 years (Thornton *et al.*, 2006; Davidson *et al*., 2003; Burton, 1997).

2.5.3 Climate Projections for Africa

Projected future changes in mean seasonal rainfall in Africa are less well defined. For example, under low warming scenario, few areas show trends that significantly exceed natural 30-year variability. Under intermediate warming scenario, most models project that by the year 2050 north Africa and the interior of southern Africa will experience decreases during the growing season that exceed one standard deviation of natural variability (Thornton *et al.*, 2006). Also, Hulme *et al*. (2001) suggests that under intermediate warming scenarios, parts of equatorial East Africa will likely experience 5 to 20 per cent increased rainfall from December to February and 5 to 10 per cent decreased rainfall from June to August by the year 2050. Therefore, climatic variability and change of this magnitude will have far-reaching negative impacts on the key sensitive sectors such as water resources, food and agricultural production, human health, tourism, coastal development, and biodiversity. For example, the prediction models show that northern and southern Africa will be much hotter with a temperature increase of 4^0C or more; and drier with the precipitation falling by between 10 to 20 per cent (World Book, 2009). In Eastern Africa, including the Horn of Africa, and parts of central Africa, average rainfall is likely to increase by 15 per cent or more (Thornton *et al.*, 2006).

2.6 CLIMATE VARIABILITY AND CHANGE IN KENYA

2.6.1 The Climate in Kenya

Climate in Kenya is influenced by Inter-Tropical Convergence Zone (ITCZ), a relatively narrow belt of very low pressure and heavy precipitation that forms near the earth's equator.

The exact position of the ITCZ changes over the course of the year, migrating southwards through Kenya in October to December, and returning northwards in March, April and May. This causes Kenya to experience two distinct wet periods: the ‘short’ rains in October to December and the ‘long’ rains in March to May (EAMD, 1962). The movements of the ITCZ are sensitive to variations in the Indian Ocean sea-surface temperatures and vary from year to year. One of the most well documented ocean influences on rainfall in this region is the *El Niño Southern Oscillation* (ENSO). *El Niño* episodes usually cause greater than average rainfall in the short rainy season in October, November and December, whilst cold phases (*La Niña*) bring a drier than average season.

In Kenya, the mean annual temperature has increased by 1°C since 1960, an average rate of 0.21°C per decade (WWF, 2006). This increase has been most rapid in the months of March, April and May (0.29°C per decade) and lowest in June, July, August and September (0.19°C per decade). Furthermore, daily temperature observations show significantly increasing trends in the frequency of hot days, and larger increasing trends in the frequency of hot nights. However, the average number of ‘hot’ days per year in Kenya has increased by 57 per cent between 1960 and 2003. The rate of increase is seen most strongly in March, April and May when the average number of hot days has increased by 5.8 days per month, thus an additional 18.8 per cent of March, April and May days over this period (WWF, 2006).

Similarly, the average number of hot nights per year has increased by 113 days between 1960 and 2003. The rate of increase is seen most strongly in the Months of September, October and November (SON) when the average number of hot nights has increased by 12 days per month (an additional 38.2 per cent of nights) over this period. Also, the frequency of cold days has decreased significantly in the annual records. The cold days per year have decreased by 16 (4.4 per cent of days) between 1960 and 2003. This rate of decrease is most rapid in September, October and November when the average number of cold days has decreased by 1.8 days per month (5.7 per cent of SON days) over this period. The average number of cold nights per year has decreased by 42 (11.5 per cent of SON days). This rate of decrease is most rapid in December, January and February (DJF) when the average number of cold DJF nights has decreased by 3.5 nights per month (11.4 per cent of DJF nights) over this period.

2.6.2 Impacts of Climate Variability and Change in Kenya

Scientific evidence has shown that the frequency of droughts, floods, and other extreme climate events have increased in recent years. The most recent (2010-2011) Horn of Africa drought crisis demonstrated how vulnerable we are to climate change but also presented an opportunity for Kenya to find sustainable solutions to the climate-related crises by scaling-up and unifying its social protection programs to cushion the poor against future shocks (World Bank, 2011). Other climate change impacts are sea-level rise, depletion of mountain glaciers on Mount Kenya, lowering river, lake and groundwater levels as a results of the combined effect of rising temperatures, more frequent droughts and decreasing rainfall, resulting in the disappearance of some seasonal rivers. These have adverse impacts on hydro-energy generation, agriculture and food security, forestry, wildlife and tourism, among other climate-sensitive sectors (Mutahi *et al.,* 2011).

Climate variability and change pose major threats to the environment, to economic growth and to sustainable development. In Kenya, the negative effects of climate variability and change 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. All these are further aggravated by the interaction of multiple stresses, which impact the country's prospects for long-term economic growth and sustainability (IPCC, 2007). In Kenya, the adverse impact of climate change is compounded by local environmental degradation caused by illegal encroachments, deforestation and livestock grazing. Forest cover, for instance, has fallen from 12 per cent in the 1960s to less than 2 per cent in 2003(ROK, 2010). However, due to concerted efforts in reforestation, the Kenya Forest Service (KFS) Director David Mbugua reported in an interview with Xinhua in April 28, 2012 that the country had already managed a forest cover of 5.9 percent and is on track to achieve a forest cover of 10 per cent by the year 2030.

Kenya has in recent years had its share of climate-related impacts: disasters like the recent prolonged droughts that have at times affected areas that were initially not thought to be prone to drought attacks; frost in some of the most productive agricultural areas leading to large losses and adversely impacting food security; hailstorms like those that have become common in the Nyahururu area in recent years; extreme flooding that at times comes hot on the heels of a drought; receding lake levels in many of the lakes in the Rift Valley; and drying rivers. Many of these extreme climate events have led to displacement of communities to safer grounds and migration into and out of the county. As a result, both violent and non-violent conflicts have increased, thus compromising the availability of natural resources. Slow-onset impacts on natural resources have also led to conflict as communities (and wildlife) compete over increasingly scarce pasture, water, and other ecosystem services.

2.6.3 Implications of Climate Variability and Change on Development

Climate change potentially poses one of the greatest challenges for Kenya to realise its Vision 2030, the country's development blueprint. Indeed, the World Bank affirms that poverty and vulnerability to climate change remain the most critical development challenges facing Kenya (World Bank, 2012). Close to 80 per cent of Kenya's population is rural and dependent on agriculture for basic livelihoods. This makes the country highly vulnerable to climate variability and change since 98 per cent of the country's agriculture is rain-fed, thus making the sector highly sensitive to climatic fluctuations. Besides, arable land constitutes only 17 per cent of the total land mass; the bulk of the remaining land mass is considered arid or semi-arid. Kenya is also a water-scarce country where the natural endowment of freshwater is low and where water resources are unevenly distributed.

Poor infrastructure developments in rural and ASAL areas contribute to the increased vulnerability. Particularly, high population pressure and rapid urbanisation impact negatively on the country's natural resources. The combination of these factors increases Kenya's vulnerability to climate variability and change. Therefore, the expected impacts of climate variability and change and related uncertainties will require holistic planning. Addressing climate variability and change requires 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, 2009).

Some of the climate-related challenges include increases in the incidences of waterborne and water-related diseases, crop failure, and escalation of pests and crop and livestock diseases. Other impacts include water scarcity, which may foment natural resource conflict, food insecurity and malnutrition.

2.6.4 Economic Implication of Extreme Climate Events in Kenya

Climate related events such as drought and floods have impacts on socio-economic aspects and consequently economic growth in Kenya. The continued annual burden of these extreme climatic events is estimated to cost the economy as much as USD 500 million a year. This is equivalent to approximately two per cent of the country's GDP, and is likely to stunt long-term growth (SEI, 2009). For example, the 1999 to 2000 *La Niña* 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 people and led to rationing of water and energy utilisation. Similarly, the 2006 drought affected more than 723,000 people in Kenya (SEI, 2009).

The 1997/98 *El Niño* affected almost 1.5 million people and was estimated to have a total costs of USD 0.8 to USD 1.2 billion arising from damage to infrastructure such as roads, buildings and communications, public health effects (including fatalities), and loss of crops. Moreover, other losses amounting to USD 9 million were attributed to flooding, property destruction, soil erosion, mudslides and landslides, surface and groundwater pollution, and sedimentation of dams and water reservoirs (Obati, 2005). The continued annual burden of these events leads to economic costs, approximately over USD 0.5 billion per year, an equivalent of about two per cent of the GDP, thus reducing long-term growth (SEI, 2009). There is some indication that there has been an intensification of these extreme events over recent decades and these may reflect a changing climate already. However, these impacts have also to be seen in the context of changing patterns of vulnerability; for example, from changing land-use patterns and rising populations.

2.7 VULNERABILITY

In relation to climate change, O' Brien *et al.* (2004) and Thornton *et al.* (2006) summarise two approaches in interpretation of vulnerability; an 'end-point' and a 'starting-point' (Table 2.1). The former considers that adaptations and adaptive capacity determine vulnerability, whereas the latter holds that vulnerability determines adaptive capacity. These two interpretations of vulnerability are synonymous to the two types of adaptation; reactive and proactive respectively. The starting point focuses on the proactive adaptation by taking into consideration how to increase resilience and reduce vulnerability through preparedness. The preparedness may include structural adjustments or adjustment in policies. As an end-point, emphasis is on what needs to be done to ameliorate the impacts of climate related risks and hazards on the natural and social systems.

Table 2.1: Differences in end-point and starting-point interpretation of vulnerability

Type of description	End-point interpretation	Starting point interpretation
Policy context	Mitigation and consolation	Adaptation
Main problem	Climate change	Social and economic vulnerability
Main solution to the problem	Mitigation, technical adaptation, compensation	Social adaptation, sustainable development
Policy question	What are benefits of climate change mitigation?	How can vulnerability of societies to climatic hazards be reduced?
Adaptation approach	Reactive	Proactive
Research concern	The residual (net) impacts of climate change minus adaptation	Generated by multiple processes and stressors in addition to climate change Differences in magnitude of impacts climate change between individuals and groups within a similar (socio-economic and geographical) setting
Intervention	Single approach (adaptation)	Multiple approach (adaptation and technological)
Purpose	Descriptive	Explanatory
Meaning of vulnerability	Expected net damage for a given level of global climate change	Susceptibility to climate variability and change as determined by socio-economic factors
Vulnerability and adaptive capacity	Adaptation and adaptive capacity determines vulnerability	Vulnerability determines adaptive capacity
Reference for adaptation capacity	Adaptation to future climate change	Adaptation to future climate variability
Starting point for analysis	Scenario for future hazards	Present vulnerability to climate stimuli
Main discipline	Natural sciences	Social sciences
Vulnerability approach	Integrated	Social constructivist
Time-scale and the system of focus	Long-term cross-sectional integrated vulnerability of a particular system to global climate change	Current internal integrated vulnerability of a particular group of all relevant stressors
Determinant factors	Natural or physical factors	Socio-economic/biophysical factors

Source: Partly adapted from Fussel (2005) and Thornton *et al*. (2006).

In general, most of the current literature reflects on vulnerability as a starting point. Thornton *et al.* (2006) noted that vulnerability to climate change must be seen as a state that is governed not just by climate variability and change but also by multiple processes and stressors. This allows for multiple point intervention that may go well beyond technological adaptations, to enhance peoples' ability to cope with day to day climate variability and long-term climate uncertainty.

2.8 LAND

Land as a resource is often the most important, if not the only means of livelihood, for many people in Kenya and other developing countries. All activities, be they economic or social, depend largely on land. Land is the foundation of shelter, food, work and indeed a sense of nationhood. As such, rights of land ownership and land-use not only involve emotions but also provide important ways through which political influence is practised. The 'land question' on ownership and usage has therefore continued to take centre stage. For example, in Kenya, lack of access to or ownership of land is considered one of the major causes of poverty (UNDP, 2002).

In Kenya, land is considered both a social and an economic asset. As an economic asset, land works either as a financial or production tool. Land is a factor of production and is essential for production of agricultural goods and provision of services. At the same time, land as a fundamental financial and speculative tool is often used to hedge against inflation especially in countries where the financial markets are not well developed. Moreover, financial institutions frequently prefer land as collateral in advancing credit largely because land is immobile, its depreciation over time is small and its value is not eroded by inflation (Biswanger and Rosenzweig, 1986).

The arrangements that communities establish concerning ownership and use of land depend on, among other factors, the legal structures governing and regulating access and use of land. Kenya has an elaborate system of rules that govern the relationship between people and land; and between citizens and the state on land ownership and use. These rules comprise a complex system of both formal and informal constraints such as legislations and the constitution. Informal rules include informal structures such as customs, laws, and trust that constitutes informal institutional framework in land-use practices. Formal rules include political and judicial rules, economic rules, and contracts.

2.9 MAN AND ENVIRONMENT

Human-environment interactions are interactive processes. Many people in the world structure their lives in concert with their environmental contexts. For various reasons associated with climate, people can become vulnerable, that is, they are at a high risk of negative outcomes as a result of climatic events that overwhelm the adaptation options they have in place. Vulnerability to climatic changes occurs due to variation in frequency or duration of those changes or because people are constrained economically, socially or politically from responding adequately to those changes. Economic and policy factors, in and of themselves, can also result in increased vulnerability.

Rainfall seasonality influences rural land-use practices such as crop production, pastoralism and wildlife conservation; hence has implication on rural livelihoods especially in Kenya, where rainfall is bimodal and characterised by spatial and temporal uncertainty. For instance, in 1997, there was a severe drought, which was followed by an *El Niño* that produced about five-fold increase in rainfall in 1998. This was then followed by drought that was among the worst on record in 1999 (WFP, 2000). Other climate analyses suggest that there will be highly differential impacts of climate variability and change in Kenya and other parts of East Africa to the middle of the 21st Century (WWF, 2006). Parts of East Africa will become drier, with considerable reduction in the length of the growing season. Other areas, such as southern Kenya and northern Tanzania, may become wetter, with increases in the length of the growing season (Thornton *et al.,* 2006). These changes will make fundamental changes on the ecosystem structure and functions, thereby transforming land-use activities and livelihoods.

2.9.1 Land-use and Rural Livelihoods

Land-use changes are a complex process that arises from modifications in land cover to land conversion process (Lambin and Geist, 2001). Land-use change is driven by the interaction in space and time between biophysical and human factors, and consequently influencing physical and social dimensions (Veldkamp and Verburg, 2004). The study of impacts of land-use change has attracted many researchers over the past decades who through their studies have attempted to understand land-use change, its causes and effects although most of these studies have emphasised on biophysical aspects of land-use change. There are still inadequate studies on the relationship between climate variability and change, land-use and their effects on rural livelihoods.

Livelihood strategies vary across communities and are influenced by linkages inside and outside land-use activities and household characteristics such as age, education and household size (Asambu, 1993; Nyariki and Wiggins, 1999; Amwata, 2004; Ziervogel, 2004; Tasokwa, 2011). The degree of diversification of the household activities is determined by these characteristics and by the household's or individual's objectives, such as risk management practices, consumer preferences, and/or strategies available to cope with shocks. However, diversification increases household resilience and the choices of the household are constrained by the combination of assets (productive, natural, human, cultural, public and social) that can be accessed. Households with assets are better able to cope with adverse events and hazards (Amwata, 2004).

The current study addresses human adaptation, vulnerability to climate variability and land-use change among the rural households. Climate variability and change are major threats limiting opportunities for sustainable development. For example, crop yields in sub-Saharan Africa (SSA) are projected to fall by 20 per cent due to climate variability and change. It has been projected that as climate variability and change pushes the world towards more extreme weather events, more and more people would be exposed to recurrent disasters. The realities of climate variability and change are reflected in the melting of mountain glaciers, sea level rise, reduced agricultural production and increased water shortages. For example, an ice cap on Mount Kenya has shrunk by 40 per cent since 1963 (WWF, 2006).

Droughts and floods are common problems impacting on different parts of the region with devastating results on people and the environment. Millions of people face famine with relentless regularity, increasing their vulnerability to disease and other hardships. For example, in the early 2003, about 25 million people faced famine, and by April 2003, this figure rose to 40 million. In southern Africa, for example, much of the famine in 2003 was attributed to the severe drought of 2002/2003. Similarly, for countries in the Horn of Africa such as Sudan, Eritrea and Ethiopia, famine is mainly a result of drought (Wasonga *et al.*, 2010); although in Ethiopia and Eritrea war has also been a contributory factor. A total of 13.6 million people in the two countries faced immediate food shortages in the early 2003. In Mozambique, the floods in 2000, the worst in 150 years, left the country's lowlands in the Limpopo River basin inundated for up to three months, affecting the plant resources upon which people relied.

2.9.2 Integrating Climate Information and Rural Livelihoods

Impacts of climate variability and change on rural households can be reduced by distributing climate data regarding seasonal climate forecasts to help households make informed land-use decisions and adapt to the changing climate conditions. Some farmers have already started to use this information and are preparing themselves for dry conditions by planting drought tolerant crops (Patt *et al*., 2005). Food production can be improved in dry areas when governments and/or non-governmental organizations use climate forecasts to plan land production. For instance, farmers can take advantage of climate forecasts by planting drought tolerant and higher-yield crops, long season maize when wetter than usual growing seasons are forecast. While seasonal forecasts can be useful in some situations, it should be noted that they cannot be applied everywhere and that many times they do not consider multiple climate extremes; for example, they may forecast drought but not extreme rainfall as was in 1997/1998. The aforementioned approaches are just a few of the many examples that governments, organizations, and communities need to consider in order to adapt to the challenges of subsistence food production and assure future food security (Patt *et al*., 2005; Ziervogel, 2004).

2.9.3 Linking Climate, Poverty and Food Security

2.9.3.1 Poverty

Poverty is a multi-dimensional phenomenon, defined and measured in a multitude of ways. In many cases, poverty has been defined and measured in economic welfare terms such as income or consumption. An individual is poor if he/she falls below a predetermined level of economic welfare deemed to constitute a reasonable minimum in some absolute level or by the standards of a specific society (Lipton and Ravallion, 1995). Though most poverty assessments have been done using this approach, there exist other facets and measurements of poverty, for example, the UNDP's Human Development Index (HDI) and qualitative measures, particularly participatory poverty assessments. Income and poverty studies may use either income or consumption to determine levels of poverty. The use of consumption data is often justified as being better than the use of income data as an indicator of long-term welfare, and such data are often believed to be easier to collect and thus to generate less measurement errors. However, some analyses using both income and consumption do not find consumption to be clearly superior to income as an indicator of long-term economic welfare (Deaton, 1997; Suri *et al.*, 2008) due to the limited ability to smooth consumption in the face of shocks. Also, analyses done in Kenya using expenditure data from the Central Bureau of Statistics and income data from Tegemeo Institute do not differ much (Tschirley and Mathenge, 2003; Suri *et al.*, 2008).

The Government of Kenya (GOK) applies a range of different poverty lines which are measured in different ways, all based on either consumption or expenditure. In terms of consumption, the food poverty line is based on the cost of consuming 2,250 kilocalories per adult equivalent per day, while the absolute or overall poverty line relates to survival food needs and basic non-food needs. In addition, there is the category of hardcore poverty, which refers to households that would not meet their minimum food requirements even if they allocated all their income on food. Thus, households are deemed to be absolute poor if they cannot meet their nutritional and other basic requirements, food poor if they cannot meet all their nutritional needs due to expenditure on other basic non-food essentials, and hardcore poor if they are unable to meet their basic food needs even by foregoing other essentials. The 2005/06 Kenya Integrated Household Budget Survey (KIHBS) estimated the food poverty line in monthly adult equivalent terms as being Kshs. 1,474 in urban areas (compared with Kshs. 998 in rural areas). The absolute poverty line in monthly adult equivalent terms was computed as Kshs. 2,913 for urban areas and Kshs. 1,562 for rural areas (Oxfam International, 2009).

2.9.3.2 Food Security and Climate Change

Agriculture is important for food security in two ways: it produces the food people eat; and (perhaps even more important) it provides the primary source of livelihood for 36 per cent of the world's total workforce. In the heavily populated countries of Asia and the Pacific, this share ranges from 40 to 50 per cent, and in sub-Saharan Africa, Kenya included, two-thirds of the working population still make their living from agriculture (ILO, 2007). If agricultural production in the low income developing countries of Asia and Africa is adversely affected by climate change, the livelihoods of large numbers of the rural poor will be put at risk and their vulnerability to food insecurity increased.

Food security prevails when aggregate production in the year is enough for the existing population at any given time. In case the global food insecurity occurs, global food price increases affecting most people of low income, net food importing countries like Kenya. Millennium Development Goals report (United Nations, 2010) draws attention to the challenges facing the world in eradicating extreme poverty and hunger (Goal 1). The hunger reduction target of halving the proportion of people who suffer from hunger by 2015 (using 1990 as the baseline) is unlikely to be met on a global basis (Nelson *et al.,* 2010). Simulation studies on the effects of climate change report price rise of major staples from 10 to 60 per cent by 2030 (Hertel *et al.,* 2010). A number of studies have quantified the impacts of climate change on food security (Fischer *et al.,* 2002; Schmidhuber and Tubiello, 2007). Climate variability and change do not only decrease the food production but also increases the food price and also damages food supply chain infrastructure (Gregory *et al.,* 2005).

Almost all relevant studies report an increase in risks of hunger under different climate scenarios but with varying effects on different parts of the world. The findings more or less converge on the point that food production will get affected more in the hot than in the cold regions. The reason is that in the hot regions of the world both heat stress and other parameters such as moisture and pest spread affect production whereas in the cold regions the heat stress is less expected. However, some crops like apple can have a risk of heat stress even in cold regions. There may be other crops getting affected in such regions but information is very limited. Thus, climate variability and change are feared to increase risks of global food insecurity. Even though the global food security is assured in aggregate, less developed countries like Kenya suffer more from short supply, imperfect food trade and price rise. Vulnerability of such countries depends on domestic food self-sufficiency. The more food sufficient is a country, the less vulnerable it is to the external shocks on food trade and price.

Any climatic change or deviation from the norm directly affects agricultural production and food security given that over 70 per cent of the population in Kenya lives in the rural areas and relies on agricultural activities for their livelihoods. This is exacerbated by the fact that agriculture is predominantly rain-fed, and thus any changes in the rainfall pattern have a significant effect on agricultural activities.

Brett (2009) has outlined four channels by which climate change affects food security. These are briefly discussed below.

1. **Temperature increase**. Higher temperatures lead to heat stress for plants, increasing sterility and lowering overall productivity. Higher temperatures also increase evaporation from plants and soils, increasing water requirements while lowering water availability.
2. **Changing ecological patterns**. In many places, growing seasons are changing, ecological niches are shifting, and rainfall is becoming more unpredictable and unreliable both in its timing and its volume. This is leading to greater uncertainty and heightened risks for farmers, and potentially eroding the value of traditional agricultural knowledge such as when to plant particular crops.
3. **Rising sea levels**. Rising seas contaminate coastal freshwater aquifers with salt water. Several small island states already have serious problems with water quality, which affects agricultural productivity. Higher seas also make communities more vulnerable to storm surges which can be 5-6 metres high. The storm surge from cyclone Nargis travelled 35 kilometres inland, killing 140,000 people and flooding around 14,400 km in Australia, an area one third the size of Switzerland.
4. **Water**. The interactions between climate change, water scarcity and declines in agricultural productivity could lead to regional tensions and even open conflict between states already struggling with inadequate water supplies due to rising populations and over-pumping of groundwater.

Moreover, FAO (2008) further stresses that climate variability and change affect all four dimensions of food security: food availability, food accessibility, food utilisation and food systems stability. All these have implications on human health, livelihood assets, food production and distribution channels, as well as changing purchasing power and market flows. Thus, the impacts may be short term, resulting in more frequent and more intense extreme weather events, and long term, caused by changing temperatures and precipitation patterns.

2.10 IDENTIFIED GAPS

Many scholars have conducted studies on various different aspects to help in the management of the drylands. In Africa, most of the studies have either focused on land-use systems, climate or socio-economic parameters in isolation. Raddatz (2005) revealed the significance of weather shocks to growth performance in low income countries like Nigeria. He found that climatic changes including floods, droughts, extreme temperatures and windstorms have adverse implication for economic growth. However, his study does not take note of the land-use systems that coexist as a unit in the drylands of Nigeria. Besides, irrespective of shocks, food is indeed a basic necessity of life and a key requirement for healthy and productive life. It is also essential for enhancing the economic, political and strategic conditions of a nation as well as the states within the nation.

The potential to adapt or mitigate the impact of climate variability and change on agriculture has mainly been studied in highly intensive agricultural areas or in large scale, such as the Asia-Pacific Region, Europe and the United States where model simulations are commonly used (Luo and Lin, 1999; Polsky and Easterling, 2001; Olesen and Bindi, 2002). Such large-scale models are inadequate for use on a local level (Reilly and schimmelpfennig, 1999), and hence more site-specific studies are needed. Johnston and Chiotti (2000) stress the importance of studying adaptation at the individual farm Level. Local level studies of farmers' perception, response and adaptation to climate variability has been carried out (Ovuka and Lindqvist, 2000; Roncoli *et al.*, 2001; Vedwan and Rhoades, 2001). These studies from Asia and Africa have been biased towards farmers' livelihoods and adaptation strategies, ignoring the land-use systems approach.

Akolade (2011) conducted a study to investigate the effect of climate variability on agricultural livelihoods in Lagos State, Nigeria. His focus was on developing a precipitation adequacy index that incorporates the spatial and temporal variability of precipitation. He further accentuated on staggered planting, crop diversification and water resources development as crucial crop adaptation strategies for the preservation of livelihoods against rainfall fluctuations. His study emphasised on crops, ignoring other land-use practices such as livestock, which have overlaps with crops and also contribute significantly to the Nigerian Economy. Biogaard and Seaquist (2005) did an assessment on the impacts of climate change on primary production and the possible impacts of such changes on the rural population of

Northern China. His study was more similar to the current study but emphasised more on rainfall. Besides, his study was more descriptive and the fact that Northern China and Southern Rangelands have geographical differences, there was need for more location specific studies.

Also, Brant (2007) assessed vulnerability of households in North Brazil. This study used the probit model to establish factors influencing household vulnerability to poverty. It emphasised a lot on extreme weather events and livelihoods but paid limited attention to the different land-use systems that co-exist together. His assumption was that when extreme weather events occur, households are impacted the same way. This may not be true given that each land-use system has its peculiarities and similarities that need to be addressed in terms of innovative adaptation options. His study also emphasised on rainfall and ignored the contribution of other climate related factors like temperature and rainfall distribution. Tasokwa (2011) also studied the impact of climate variability and extreme weather events on gender and household vulnerability to food insecurity. Her study is similar to the current study only that she focused more on gender and climate variability while the current study focuses on land-use and climate variability. Besides, her study was conducted in Malawi. Therefore due to differences in geographical location, the recommendations obtained may be used for lesson learning for Kenya and not for duplication.

Ndathi *et al.* (2011) conducted a study on climate variability and generation of dry season ruminant livestock feeding strategies in south eastern Kenya. This study focused more on livestock production systems and less on other production systems. Further, Bryan *et al.* (2010) conducted a study in seven former districts of Kenya to evaluate the different coping strategies and adaptation options. His study was more centred on developing the determinants of adaptation options rather than vulnerability. However, the understanding of vulnerability is a pre-requisite for identifying and evaluating the adaptation options. Savatia (2009) also assessed the impacts of climate change on water and pasture resources among the Turkana and Pokot pastoralists. His assessment focused on pastoral production systems paying limited attention to cropping systems.

All the previous studies have contributed to the growing knowledge and climate variability and their link with livelihoods including food security. However, their interactions with land-use systems have been limited. As a result, the current study provides evidence for policy direction in holistic land-use systems approach as a pre-requisite for the sustainable management of the ASALs.

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CHAPTER THREE

STUDY AREA

3.1 INTRODUCTION

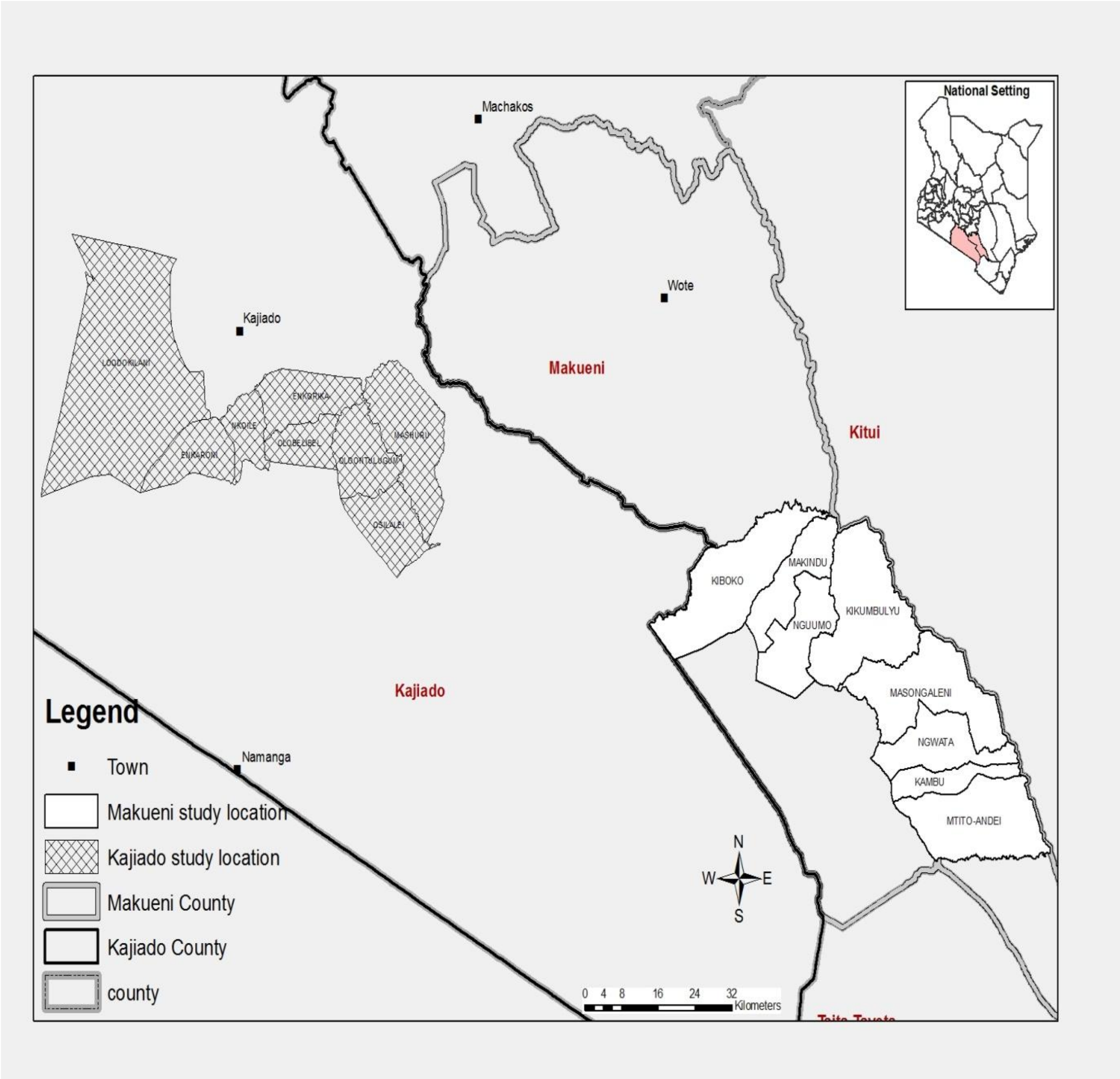
This chapter describes the study area in the southern rangelands of Kenya. Southern rangelands are located in the southern part of Kenya and include Kajiado, Makueni, Mwingi, Machakos and Kitui Counties. Two counties namely Makueni and Kajiado form the study area for the current research (Figure 3.1). These two counties were selected because the researcher had prior experience in these counties and also data were readily available. The locations within each of the county was listed and prioritised in terms of the most to the least vulnerable to extreme weather events. Eight locations were selected in each of the two counties, giving a total of sixteen locations. The chapter provides an overview of locations, population dynamics, land production systems, biophysical factors and climate related events in the two counties.

3.2 KAJIADO COUNTY

3.2.1 Location

Kajiado County, formerly known as Kajiado District is among the 18 counties that form the former expansive Rift Valley Province of Kenya (Figure 3.2). The county occupies about 19,600 km^2 (CBS, 1981). It is situated between longitudes 36^0 5’ and 37^0 5’ east and latitudes 1^0 0’ and 3º 0’ south (ROK, 2005). It is roughly triangular, and is bordered by the Nairobi-Mombasa railway to the north-east, the border with Tanzania to the south, and the western wall of the Rift Valley to the west (ROK, 2009a). The eastern boundary is formed by the Chyulu Range and western limit of Tsavo National Park. The county has been divided into four eco-zones: the Rift Valley, the upland Athi Kapiti Plains, the Central Hills, and the Amboseli Plains (ROK, 1982).

Figure 3.1: Location of Study sites of Kajiado and Makueni Counties

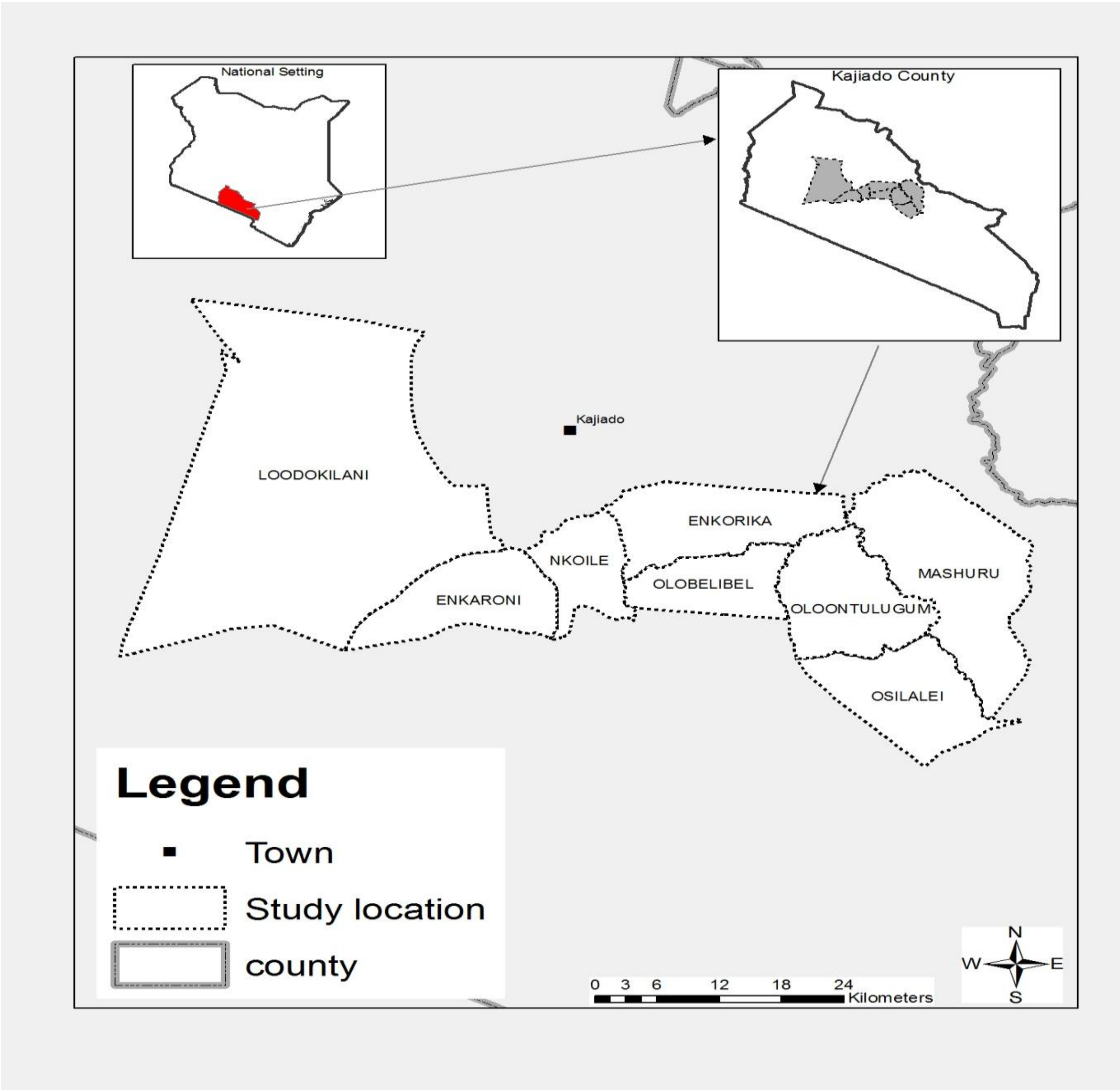


3.2.2 Biophysical Features

3.2.2.1 Topography

The main topographical features in the county are plains, valley and occasional volcanic hills. The land varies in altitude from about 500 m above sea level (a.s.l.) around Lake Magadi to about 2,500 m a.s.l. in the Ngong Hills. The county has three topographical features, namely Rift Valley, Athi Kapiti and Central Broken Ground (CBS, 1981). First, the Rift Valley is a low depression on the western side of the county running from north to south. It is made up of steep faults giving rise to a plateau, scarps and a structural plain. The plateau has important features such as Mt. Suswa, Lake Magadi and Lake Natron. Both lakes have substantial deposits of soda ash, although commercial exploitation takes place only at Lake Magadi. On the far western Nguruman Escarpment, there are three main rivers, namely Oloibortoto, Entasopia and Sampu, which are important for the irrigation of horticultural crops in Nguruman area. The altitude is between 600 and 1,740 m a.s.l. (ROK, 2009a).

Figure 3.2: Kajiado County and its administrative boundaries



Second, the Athi Kapiti Plains consist mainly of gently undulating slopes, which become rolling and hilly towards Ngong Hills with an altitude of 1,580 to 2,460 m a.s.l. The hills are the catchment areas for Athi River, which is fed by the permanent Mbagathi and Kiserian tributaries. These rivers are important sources of water for domestic use and small-scale farming. Lastly, the Central Broken Ground comprises 20 to 70 km wide stretch from north-eastern boarder across the county to the southwest at an altitude ranging from 1,220 to 2,073 m a.s.l. Criss-crossing the area are also dry riverbeds, which are sources of sand for the building and construction industry in Kajiado and Nairobi (Berger, 1993; ROK, 2009a). The major rivers in the county are Athi, Ewaso Ngiro and Pakase. Although most of the county is well drained, impeded drainage normally exists within the central part because of the higher percentage of clay content in the soil, which contributes to seasonal flooding. These parts together with southern parts of the county are served by a number of water sources, some of which are seasonal and include Uaso Ngiro that enters Kajiado through Mosiro. There are also several streams flowing from the eastern face of Nguruman Escarpment and Loita Hills.

3.2.2.2 Climate Information

Kajiado County has a bimodal rainfall pattern that is influenced by altitude. The mean annual rainfall ranges from 300 to 800 mm.[1] However, heavy rains occur around Ngong Hills, Chyulu Hills and Nguruman Escarpment, receiving 1,250 mm of rainfall per annum, and Magadi, receiving less than 500 mm of rainfall per annum. The analysis of rainfall for the two wet seasons indicates that most areas receive 50 per cent of annual rainfall during the March to May period and 30 per cent during the October to December period (ROK, 2009a). The distribution of rainfall between the two seasons changes gradually from east to west across Kajiado County. In eastern Kajiado more rain falls during the "short rains" than during the "long rains". In western Kajiado most of the rain falls during the "long rains" (Berger, 1993).

Agro-ecological zones (AEZ) influence economic activities in the county. Most of Kajiado County lies in the semi-arid and arid zones (zones V and VI). About 55 per cent of the total area is under AEZ V; 35 per cent under AEZ VI, and eight per cent under AEZs II-IV; thus making Kajiado County one of the ASAL counties in Kenya. Temperatures range from a mean maximum of about 34^0C around Lake Magadi to a mean minimum of 22^0C on the slopes of Ngong Hills (ROK, 2009a). Agro-ecological zone V receives 500 to 1,000 mm of annual rainfall, sustains 90 to 180 plant growing days, and has a moisture index of 25 to 50 per cent (Sombroek *et al.*, 1982). The lower rainfall areas of this zone are used for grazing. Cropping and mixed crop and livestock systems dominate the higher rainfall areas. Farmers grow millet, sorghum, groundnut, maize, beans, pigeon peas and cowpeas. The vegetation is grassland interspersed with *Acacia drepanolobium* (ASAL, 1990). AEZ VI receives 0 to 500

[1] http://www.fao.org/wairdocs/ILRI/x5552E/x5552e04.htm. Chapter 2: Introduction to the Kenyan rangelands and Kajiado County. Retrieved on 23/10/2011.

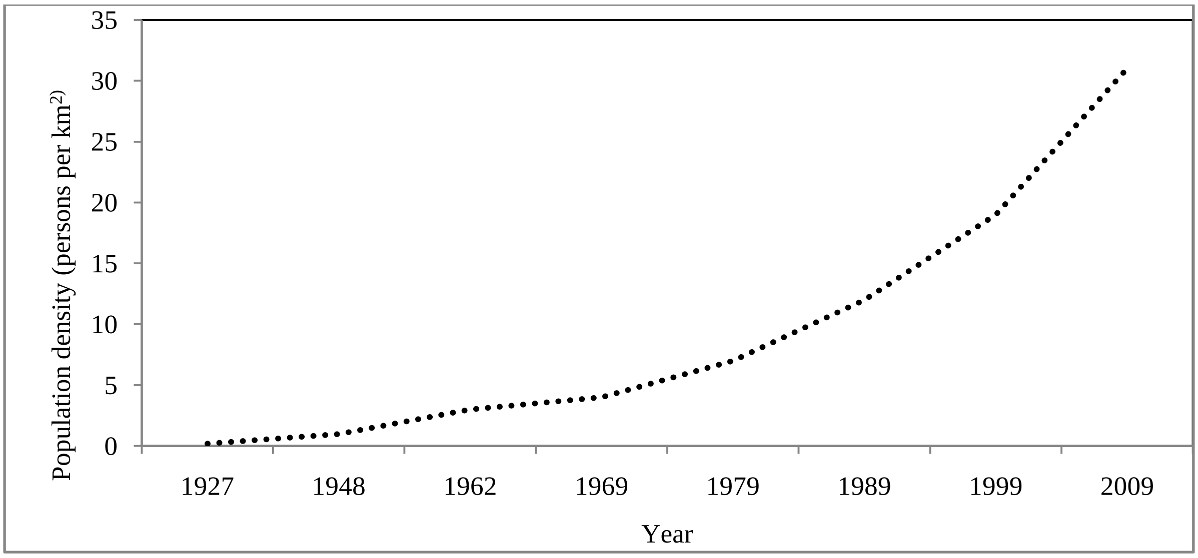
mm of rainfall annually and is capable of sustaining plant life for less than 90 growth days. This low amount of rainfall and its erratic distribution prevent sustainable cropping in most years; some cropping takes place in oases or irrigated areas. Plant cover consists of short annual grasses, legumes, scattered shrubs and trees. Agro-ecological zones II-IV are characterised as humid to sub-humid zones that receive 1,000 mm to 1,500 mm of rainfall, with between 180 to 270 growing days (Jahnke, 1982).

3.2.3 Demographic Features

Kajiado County is dominated by semi-nomadic pastoralists, the Maasai, who have been practising transhumance as their traditional mode of life under communal land ownership. However, this lifestyle has undergone transitional changes due to land reforms particularly adjudication and sub-divisions, which have seen the emergence of individual or private land ownership. Moreover, the privatisation of tenure has promoted land sales thus opening up the pastoral ancestral land to immigrants from high potential areas, especially the farming communities from the neighbouring counties and even from other parts of the country. The areas most affected include Ngong, Loitokitok, and Nguruman Divisions and the foot slopes of Namanga Hills. This has been intensified by the proximity of some divisions to Nairobi, the Capital City of Kenya, thus further attracting more immigrants.

The 2009 population census revealed that Kajiado County had a population of 687,312 people. In 1999 and 1989, the populations were 406,054 and 258,659 respectively (CBS, 2009). This gives an annual growth rate of 4.5 per cent, a rate that is significantly above the national annual growth rate of 2.9 per cent. Similarly, the county population density has tremendously increased over the years from 0.2, 1, 3, 4, 7, 12, 17 and 31 persons per km^2 in 1927, 1948, 1962, 1969, 1979, 1989, 1999 and 2009 respectively (ROK, 2002a; CBS, 2009). Figure 3.3 shows how the population density of Kajiado County has rapidly increased over the years (ROK, 2002a).

Figure 3.3: Changes in population density for Kajiado County from 1927 to 2009



Source of Data: ROK (2002a, 2005, 2009a).

3.2.4 Disaster Management

Disaster is a serious disruption of the functioning of any society, causing major human, property, socio-economic and environmental losses which exceed the ability of the affected society to cope using only its own resources (Orindi *et al.*, 2006). The most common disasters that have occurred in the county are drought and famine. Most parts of the county have been affected by drought and the effects have always been catastrophic as they have led to major losses in livestock and successive crop failures. For example, the 2004 to 2007 drought resulted in over 70 per cent livestock deaths, leaving the communities with no source of income and food (ROK, 2009a). Flash floods, winds and poverty in the county have forced people to resort to charcoal burning, resulting in deforestation and consequently denudation of land, in return causing flash floods. Besides, limited wind breaks have contributed significantly to wind erosion.

3.3 MAKUENI COUNTY

3.3.1 Location

Makueni County is one of the 13 counties that form the former Eastern Province and one of the four that comprise Ukambani region (Figure 3.4). It was carved from former Machakos County in 1992 and boarders Kajiado County to the west, Taita-Taveta to the south, Kitui to the east and Machakos to the north. The county lies between Latitude 1º 35´ south and Longitude 37º 10´ and 38º 30´ east (ROK, 2009b). Thus, it is located in the southern end of the former Eastern Province and covers an area of 7,965.8 km^2 with a population of 884,527 in 2009 and an annual growth rate of 2.8 per cent (CBS, 2009). There are three main livelihood zones in the county; marginal mixed farming, coffee/dairy/irrigation zone and food crops/cotton/livestock zone. The major staple crop is maize. Other crops grown in order of importance are cowpeas, beans, pigeon peas and green grams.

3.3.2 Biophysical Features

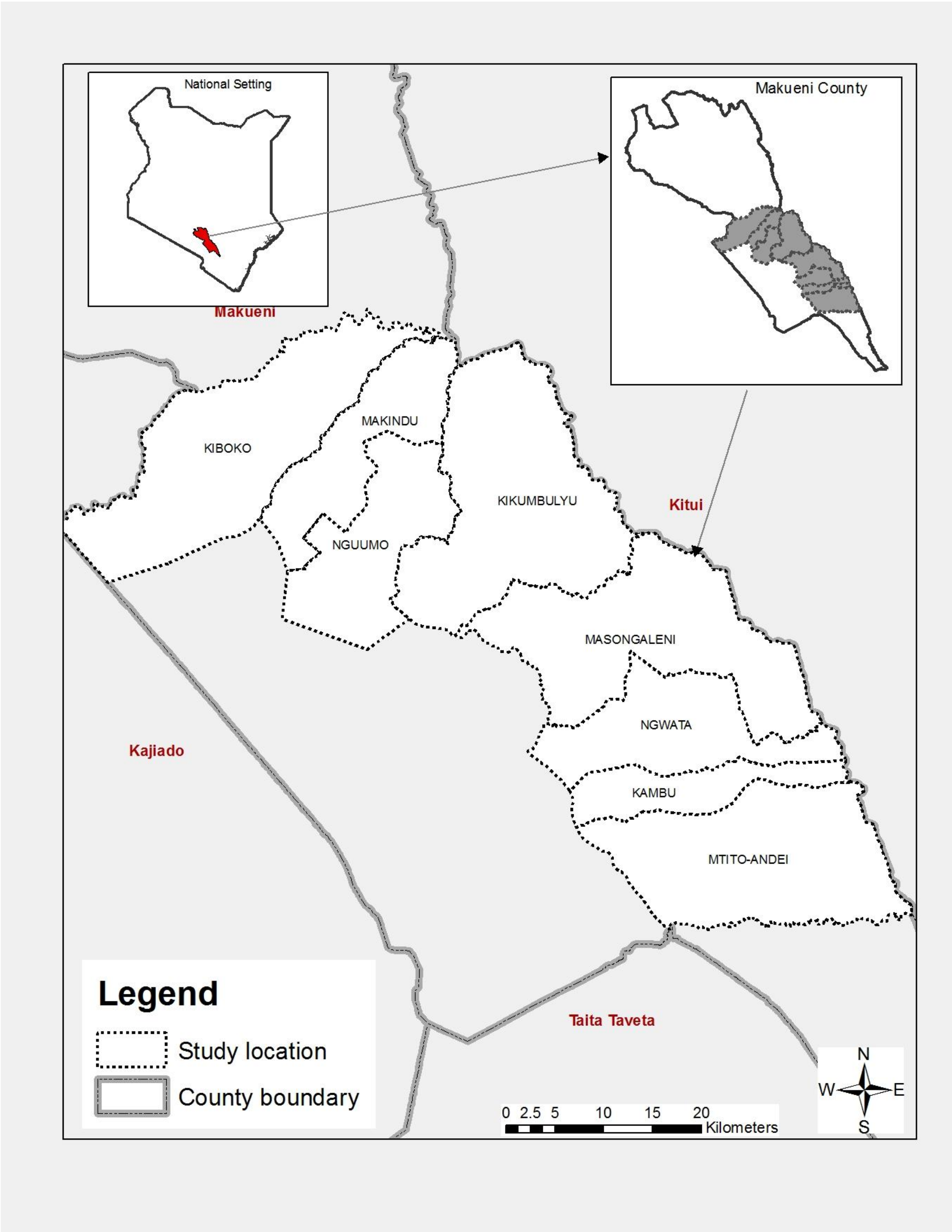
3.3.2.1 Topography

The major land formation in Makueni County includes the volcanic Chyulu Hills, which lie along the south west border of the county. The Mbooni and Kilungu Hills rise to a height of 1,900 m a.s.l. The land lies slightly below 600 m a.s.l. in Tsavo at the southern end of the county. The southern part of the county is low-lying grassland, which receives little rainfall but has an enormous potential for ranching. The northern part of the county is hilly with medium rainfall and has potential for food crops, dairy, horticulture and coffee production. This part of the county (mainly Kilungu, Kaiti, Kilome and Mbooni Divisions) has few natural but a lot of planted trees. The mean temperatures in the county range from 20.2^0C to 24.6^0C but during drought, temperatures have gone as high as 32^0C (ROK, 2002b; 2009b).

3.3.2.2 Climate and Rainfall

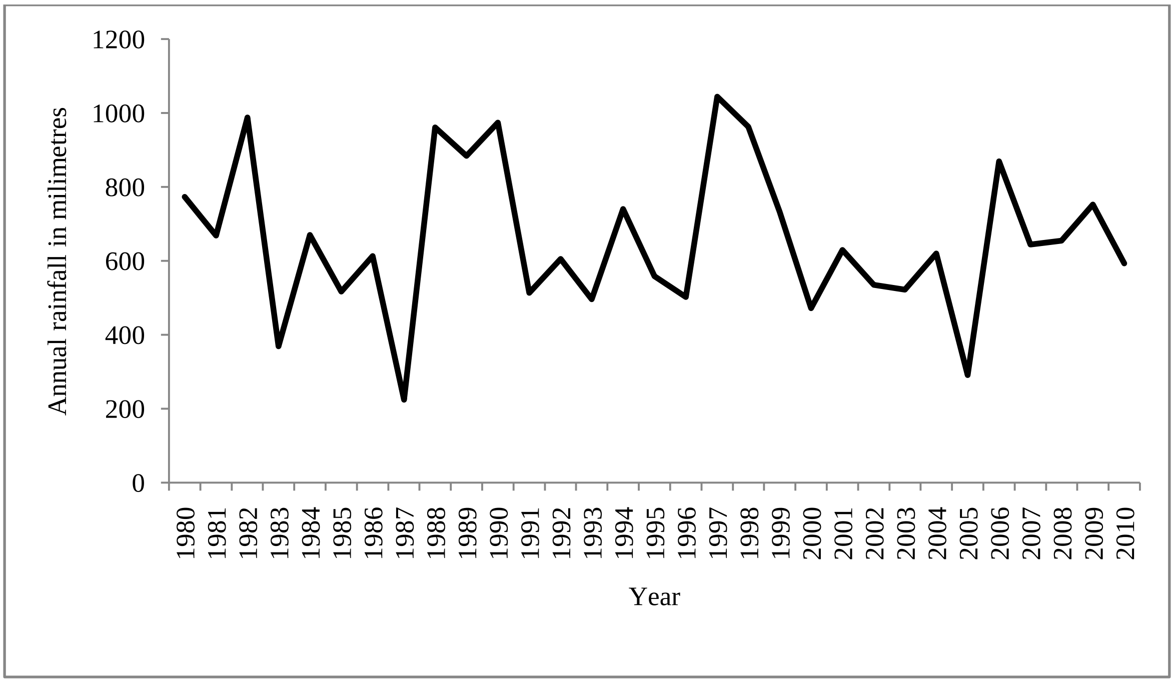
The county is characterised by extreme rainfall variability. Typically good seasons are interspersed with extremely dry seasons, and variations in the onset of rainy seasons add to the difficulty of ensuring adequate food production. The county has two rainy seasons, with two peaks in March/April (long rains) and November/December (short rains) under the influence of the Inter-Tropical Convergence Zone. June to October is a long dry period, while January to February is a short one. The highest rains fall along a northwest/southeast trending axis of the Chyulu Hills or the hilly parts of the county that receive 800 to 1,200 mm of rainfall per year, while the rest of the county receives less rainfall at about 500 mm per annum (Gichuki, 2000). The county has four meteorological stations. The annual rainfall for Makueni County is shown in Figure 3.5. The high temperature experienced in the low-lying areas causes high evaporation. The annual averages for rainfall, evapotranspiration and temperature are 600 mm, 200 mm, and 23°C respectively (Nyangito *et al.,* 2008). The driest months are June to September (Musimba *et al.*, 2004).

Figure 3.4: Makueni County and its administrative boundaries



The overall drainage pattern in the county is from west to east. There are a few permanent rivers and streams in the county. Athi River is the only major perennial river that drains the entire county. Mbooni and Kilungu Hills have a few perennial streams whose flow is extremely intermittent at low altitudes. Other rivers that drain the county include River Kambu, River Kiboko and River Kibwezi.

Figure 3.5: Mean annual rainfall in Makueni County from 1965 to 2010



Source of Data: Kiboko Research Station, DWA, KEFRI and Makindu Meteorological Stations, Kenya.

3.3.3 Demographic Characteristics

According to the 2009 population census, Makueni County had a population of 884,527. The population was 771,999 in 1999 and 839,155 in 2002. Although there is a significant drop in the population growth rate, it is still growing every year (ROK, 2009b). The upsurge in population will continue to accelerate the conversion of natural vegetation to farmland, settlement and infrastructural development. Already the county is experiencing a problem of squatters with increasing numbers of people moving down from the dense sub-humid areas to the fragile lowlands. In general, the county is sparsely populated with the exception of Mbooni and Kilungu Divisions that have population densities of about 400 persons per km^2 (ROK, 2002b). The high population densities in some of the divisions could be attributed to the hilly terrain that has rich soils. Also, these divisions lie on the windward side, and are thus potentially likely to benefit from good rainfall that supports agriculture. However, the study sites fall under Makindu, Mtito Andei, Masongeleni, Kambu and Kibwezi, which are located in the lowlands and are characterised by low and erratic rainfall. The high population pressure coupled with scarcity of land in the high potential areas is pushing people from the sub-humid areas to the lowlands.

In an attempt to address the high population pressure, the government has opened up new settlement schemes in Kibwezi, Kiboko, Masongaleni and Mikululo areas. Even with these attempts, the number of squatters is still on the rise, currently estimated at 30,000 families. This figure is likely to go up, given government projections (ROK, 2009b). Likewise, upcoming trading centres, including Kathonzweni, Matiliku, Kibwezi, Mtito Andei, Makindu and Mukuyuni that offer opportunities for investment, trade and temporary employment are likely to attract more immigrants both from within and outside the county.

In terms of structure, the county's population is generally youthful with those below 15 years of age accounting for 47 per cent of the total population. In 2002, the population below 15 years was 395,544, and the figure was estimated at 467,904 persons in 2008 as shown in Table 3.1. Nevertheless, the dependency ratio has remained more or less constant even with an increase in human population. The individuals who are less than 15 years together with the elderly, those more than 64 years of age, constitute the *de facto* population. This refers to individuals who are unable to work and contribute to the generation of resources to the household. This group accounts for 51.8 per cent of the total population and gives a dependency ratio of 100:109. This implies that for every 100 economically active persons there are 109 persons who are dependants. However, due to unemployment, more than 50 per cent of the economically active are unemployed. Thus, the dependents are more than the economically active, and this is likely to exacerbate further due to high rates of unemployment.

Table 3.1: Dependency ratio for Makueni County

Population Type	1999	2002	2004	2006	2008	Total
De facto	247,175	282.989	309,700	338,934	371,929	155,0727
Active	158,876	181,796	200,066	217,857	238,420	997,015
Total	406,051	464,785	509,766	556,791	610,349	2,547,742
Dependency ratio	100:156	100:156	100:155	100:156	100:156	100:156

Source: ROK (2001).

The soils are well drained and have a medium texture, and deep with low acidity. The soils along the Chyulu Hills are volcanic while lowlands are characterised by sandy soils. The vegetation is composed of herbaceous and grazing zones at Kiboko, and forest shrubland at Kibwezi. The main species are *Commiphora* and *Acacia*, besides the perennial grasses such as *Chloris roxyburghiana*, *Cenchrus ciliaris, Sporobolus* species, *Eragrostis superba* and *Digitaria macroblephera* (ROK, 2000b; Musimba *et al.,* 2004; ROK, 2009b).

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CHAPTER FOUR

METHODOLOGY

4.1 INTRODUCTION

This chapter covers the methods that were used to obtain both primary and secondary data needed to achieve the study objectives. Primary data were acquired mainly from surveys including questionnaire interviews, direct observations and Focus Group Discussions. In addition, secondary data were obtained from existing literature including unpublished and published reports from relevant ministry departments, peer-reviewed journals and on line resources.

4.2 STUDY DESIGN

This study employed a multistage sampling technique. First, two counties were purposively sampled based on the location, culture and proneness to climate related events. Then locations within these two counties were listed and categorised on the basis of the various land-use systems and the extent to which they were prone to extreme climate events. This was then followed by random selection of eight locations from Makueni and eight from Kajiado Counties making a total of sixteen locations. After the selection of the locations; lists of households were obtained from the local Assistant Chiefs. The households in each of the location were listed from 1 to N (N = group size) and then systematic selection of the households were carried out. Thus, the choice of the household interviewed was based on systematic sampling procedure (Prewitt, 1975). A random start was used in choosing the first household to be interviewed. Twelve households were then skipped to get the next household, and so on. For the selected households whose heads were absent, next households were interviewed, giving 100 and 98 households for Makueni and Kajiado Counties respectively.

Cross-sectional data were collected from the 100 households in Makueni County and 98 households in Kajiado County for a period of six months starting from April to September 2009. Data were collected on the socio-economic and biophysical aspects. Examples of the data collected were household characteristics, climate related historical events, climate related impacts, coping mechanisms, livelihood strategies, herd sizes, farm labour, remittances, types of crops grown, acreage cultivated and output. The information obtained was entered using Statistical Package for the Social Scientists (SPSS) for descriptive statistics and regression analysis.

To complement the cross-sectional data, time series data were collected on climate parameters and farm based parameters for a period of 31 years, starting from 1980 to 2010. Climate data included rainfall, temperature and rain days. The climate data were obtained from the National Meteorology Department namely Makindu, DWA, Kenya Forestry Research Institute (KEFRI), Kiboko Research Station and Kajiado Station.

4.3 DATA COLLECTION PROCESS

4.3.1 Reconnaissance Survey

A reconnaissance survey was conducted to familiarise with the study area as well as organise a meeting with the relevant stakeholders including the line ministries to introduce the study with respect to its objectives, expected outputs and relevance to decision making processes. The participants present during the introductory meeting included local administrators, county range officers, county agricultural officers, extension officers and local elders. This session was very instrumental as it helped in cementing local community trust as well providing more insights into areas that the stakeholders prioritised in order to enhance livelihoods in the study area. Besides, this enabled a better understanding of the peculiarities of the study area, the size of the sample frame that was considered and the identification of the champions or key informants that were pertinent to the study. All these facilitated the planning of both resources and time.

4.3.2 Training of Local Field Assistants

To promote participation and community ownership, four field assistants were recruited from the study area based on their previous experience as research assistants, qualification and knowledge of the language of communication. The training was conducted for five days to familiarise the field assistants with the objectives of the study, methods and tools to be used. This included the practical sessions on the use of a Global Positioning System (GPS) that was used to geo-reference each of the households interviewed and to establish their geographical location including their agroecological zones. This helped in categorising households interviewed into different rainfall levels.

4.3.3. Questionnaire Pre-testing

A two-week pre-test of the questionnaire was conducted. A pre-test questionnaire was used on 20 households each for Makueni and Kajiado Counties of the study area. The households involved in the questionnaire pre-test were excluded from the final survey. Pre-testing was done to check the suitability of the tools. The pilot study sites were also used to train research assistants on data collection techniques. The questionnaire was finalised taking into consideration the necessary modifications from the pilot surveys, after which the actual study was conducted.

Besides, some parts of the two counties were identified by the Government of Kenya as a local environmental monitoring site. In Kenya, Kiboko-Kibwezi is an observatory for monitoring environmental dynamics, specifically ecological, socio-economic and biophysical parameters in order to develop indicators for monitoring desertification at the local and national levels. The Kenyan Government through the relevant ministries and departments working on the environment such as the Ministry of Water and Irrigation, Ministry of Environment and Natural Resources, National Museums of Kenya, Kenya Agricultural Research Institute and Department of Resource Survey and Remote Sensing held a consultative meeting in 1995. The consultative meeting was aimed at fostering collaboration among these institutions towards a common goal of developing common indicators for environmental monitoring as well as maximising the institutions' comparative advantages. A multidisciplinary approach was used in defining the criteria and methodology to label a local environmental monitoring site also referred to as Kiboko-Kibwezi Observatory (OSS, 2001). The current study area falls within the Kiboko-Kibwezi Observatory and have prospects of feeding into the environmental decisions for the ASALs.

4.4 THE ANALYTICAL FRAMEWORK

The analytical framework for the current study builds on the previous sustainable livelihoods thinking by Chambers (1987), Chambers and Conway (1992), Carney and Ashely (1999) and

DFID (2000), which places people at the centre of vulnerability analysis (Figure 4.1). It also extends the livelihood thinking by incorporating the farm-based and household characteristics. The integration and the explicit linking of socio-economic and biophysical factors are essential for understanding household resource use, behaviour and inter-temporal changes in the quality of flow and stock resources attributed to factors such as climate variability and change.

Similar frameworks have recently been applied in bio-economic modelling of soil and water use decisions and analysis of policy and technology options (Ruben *et al.*, 1998; Shiferaw and Holden, 1999). These scholars emphasised on the edaphic and technological parameters, underestimating the role of climate and other socio-economic factors. Similarly, a study on the assessment of community resilience to climate variability and change in Sudan (Elisha *et al.*, 2005) and analyses of poverty and natural resource management in the semi-arid tropics (Shiferaw, 2006) focussed on socio-economic aspects giving limited or no attention to the role of biophysical aspects such as climate. These studies have contributed to developing proxies for vulnerability. Also, Tasokwa (2011) conducted a study on the influence of climate variability and extreme weather events on gender and household vulnerability to food insecurity in Malawi. In her study, she integrated the biophysical and socio-economic factors, with gender as the central focus. The present study deviates from Tasokwa's work with land-use systems as the main focus. Besides, the present study builds on Tasokwa's work and the previous efforts by integrating biophysical and socio-economic aspects from a systems perspective to develop a holistic model. This approach provides a framework that is interdisciplinary and dynamic in designing innovative adaptation practices aimed at fostering sustainable development, poverty reduction and minimising vulnerability to food insecurity in the southern rangelands of Makueni and Kajiado Counties and other ASALs of Kenya.

Figure 4.1 shows that biophysical factors together with socio-economic factors influence household livelihood strategies and decision-making processes over time. An individual household is the centre of the model, given that it is the unit where strategies are often developed and decisions taken to develop and maintain livelihood portfolios. In addition, a systems' viewpoint of the model denotes that biophysical factors such as climate could influence the socio-cultural and socio-economic environments of households, impacting resources, assets and savings. The resource management strategies and decision-making potential of the local people are likely to be affected. Therefore, innovative adaptation strategies may vary or similar among the land production systems, thus offer the potentials to expand the coping range, thereby minimising household vulnerability to food insecurity at a given time.

4.5 GENERAL APPROACHES

A three-stage approach was used to assess climate variability and change with particular emphasis on livelihoods and land-use at the selected locations. The stages included:

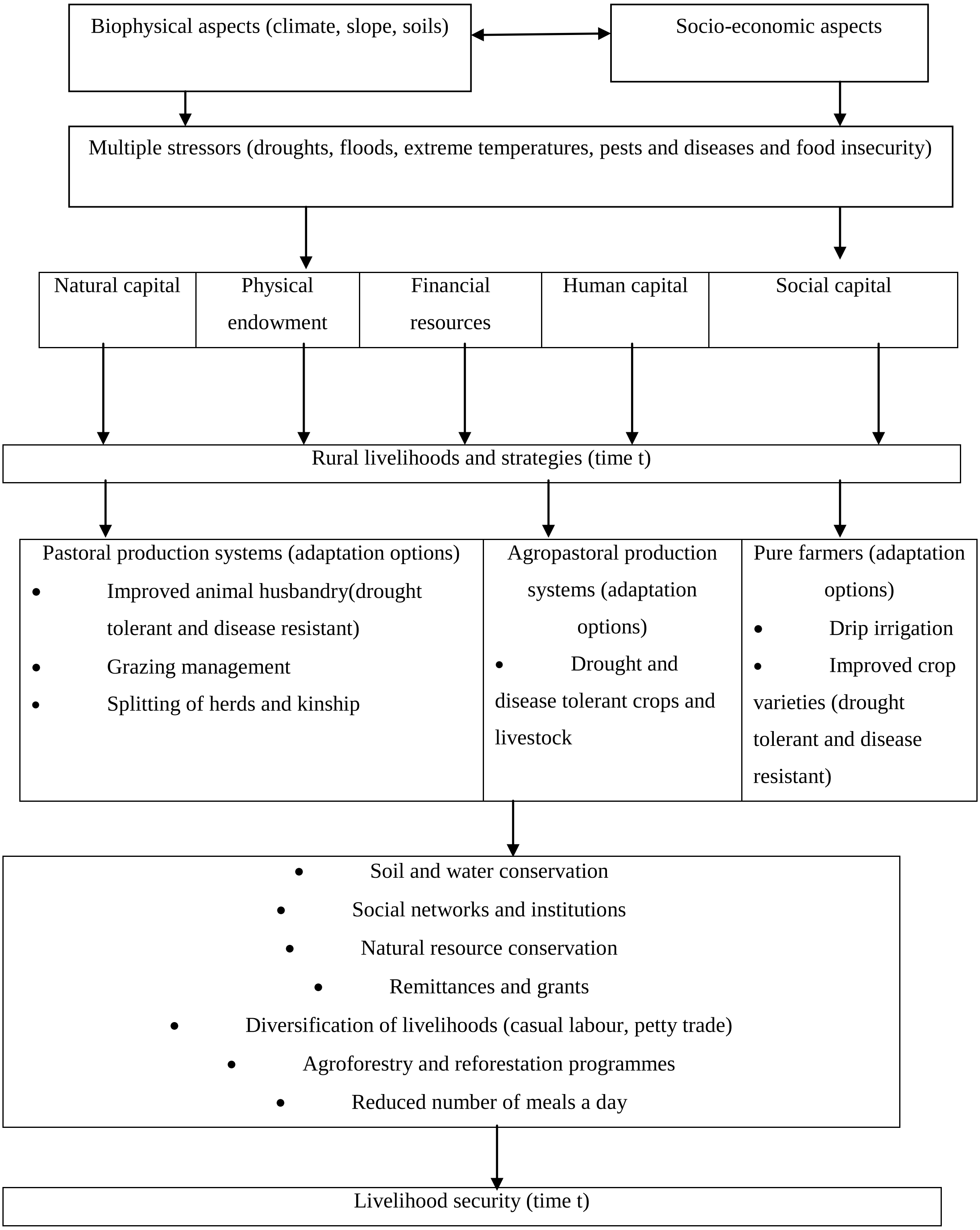
1. Stage 1: Participative spatial data collection through the use of a GPS, where the local communities and the field assistants helped in mapping resources and social amenities within the study area;
2. Stage 2: Conducting household interviews and Focus Group Discussions to document the understanding and experiences of extreme climate events and land transformations (use and ownership). This stage employed participatory approaches to collect perceptions and opinions from various households, villages and community level stakeholders on the local understanding of climate related events, their impacts on livelihoods and the evolution of adaptation strategies under different land-use systems over time; and
3. Stage 3: Analysing past climate data to understand the risks in relation to the variations in rainfall, temperature and rain days in dry and wet spells. At this stage, the frequencies of extreme climate events were documented and trends analysed.

4.6 DATA COLLECTION

4.6.1 Questionnaires Interviews

Information on various aspects was obtained through the administration of a questionnaire on individual households, selected community leaders and government officials. A questionnaire was used to solicit information from the households on climate, land-use and livelihoods strategies (Annex 1). The information collected included (1) the socio-economic characteristics of individual households including resource endowments, poverty levels, remittances, coping strategies, and infrastructural status; (2) climate-related extreme events and their impacts on specific resources such as water availability and use; (3) historical perspective on climate-related events such as famine and drought based on local people's experiences; (4) changes witnessed in the environment, water levels, indirect economic and social impacts on the local welfare, and equity; and (5) the role of gender, taking into consideration the fact that men and women manage different resources, which was likely to impact differently on livelihood strategies and resource endowment.

Figure 4.1: The analytical framework



Additional information was collected on the methods used by the meteorological departments to report and disseminate information on climate related parameters and whether the information was relevant to the households. In addition, interviews were held with relevant stakeholders on land aspects (access, use and ownership rights) and rangeland resources over time. The information generated through household interviews was further validated through FGDs, informal interviews and general observations. For more details see Hageback and Sunberg (2002).

4.6.2 Focus Group Discussions (FGDs)

Focus Group Discussions were conducted on selected groups of people based on gender and age. With the help of the local chief, village elders and extension officers, representatives from local institutions that have contributed to drought management were selected. The first criterion was that they were people who had lived in the area for more than 40 years as well as had the history and memories of the study sites, in particular the evolution of climate variability, land transformations and change in livelihoods. FGDs help create interaction between people and leads to verbally expressed thoughts and opinions about the topic in question (Hageback*et al.,* 2005). FGDs were carried out in the Masongeleni and Loodikilani Locations of Makueni and Kajiado Counties respectively (Annex 2). Participants were drawn from different villages, ensuring representation of various social groups, such as gender, age, wealth, and education level. These discussions were aimed at capturing the local knowledge on climate variability and its impacts on local communities, vulnerability, and adaptation mechanisms (proactive and reactive) to extreme weather events. Further discussions were held with other stakeholders such as County Water Officers, Environmental and Water Management Committees, local chiefs, village elders and Early Warning Systems Officers to solicit more information and knowledge on climatic variability and change. In addition, historical climate related events that have occurred in the community in relation to frequency and occurrence of hazards and disasters, land-use systems and sources of livelihoods were taken into consideration.

4.6.3 Climate Information

Literature review was carried out to establish the possible trends and patterns at the national and local levels in the long-term climate data (precipitation and temperature) collected from the Kenya Meteorological Department (KMD) and the sub-stations within the study sites, namely DWA, KEFRI, Kiboko, Kajiado and Makindu, for at least the last 30 years, the minimum needed for accurate climatic analyses for the tropics (Stewart, 1998; Wasonga, 2009; Tasokwa, 2011). The data obtained were used to calculate annual rainfall, rain days and mean annual temperatures.

4.7 DATA ANALYSIS

4.7.1 Descriptive Analysis

The data obtained were analysed using descriptive statistics and regression models to ascertain how climate variability and change, household characteristics and farm-based factors influence household vulnerability to food insecurity. First, descriptive analysis was carried out, including the generation of frequency tables, means, maximum and minimum values. This analysis yielded information on the demographic and socio-economic characteristics of the households in the study. These include age of the household head, gender of the household head, household assets and savings, household sizes, household income, herd sizes, sources of climate information, access to climate information and household geographical location. In addition, both qualitative and quantitative data were analysed using Statistical Package for the Social Scientists (SPSS) (Norusis, 1991).

4.7.2 Regressions

Regressions were carried out on both the qualitative and quantitative data to show the determinants of household vulnerability to food insecurity. Given that vulnerability cannot be measured in absolute terms, income per adult equivalent was used as a proxy for food security. The explanation is that for rural households, the priority is often to ensure they have adequate food. Thus, the first indicator of household vulnerability to food insecurity is the inability of that household to meet its food requirements.

The general status of household vulnerability to food insecurity is determined by the factors represented in the sustainable livelihood model (SLM), which may be presented as follows:

$$Income/AE = f(Human, Social, Natural, Physical, Economic\,Factors)$$

Thus, income per adult equivalent at household level is hypothesised to be influenced by human resources, social capital, physical environment, infrastructural development and economic endowment.

4.7.2.1 Determinants of Household Vulnerability

There are various definitions of vulnerability by different scholars, which vary depending on the discipline, context and understanding (Adger, 1999; Adger *et al.*, 2004; Thornton *et al.*, 2006a; IPCC, 2007; Tasokwa, 2011). This study adopts the definition of vulnerability as being the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation or stress (Turner *et al.*, 2003). Various factors shape the differences in vulnerability of individuals or groups: entitlements, personal heterogeneity, variations in social obligations, environmental location, diversification, support networks, empowerment or power relations, and access to knowledge, information and technology (Noronha, 2003). A combination of factors may increase vulnerability or enhance resilience to stresses and the capacity to cope or respond to climatic and non-climatic stresses in different ways. Within the context of climate studies, the most vulnerable are considered to be those who are most exposed to perturbations or risks, who possess a limited capacity for adaptation, and who are least resilient to recovery (Bohle *et al.*, 1994).

i. Defining the dependent variable

Vulnerability is difficult to measure. Currently there are no agreed indicators to measure the individual "components" of vulnerability. Furthermore, there is no agreed methodology on how to formulate a single composite index for vulnerability. This study attempts to contribute to the growing knowledge by analytically determining and prioritising the factors influencing household vulnerability to food insecurity in the ASALs of Kenya.

A household facing a risky situation is subject to future loss of welfare. The likelihood of experiencing future loss of welfare, generally weighted by the magnitude of expected welfare loss, is called vulnerability (Adger *et al.*, 2004). The degree of vulnerability depends on the characteristic of the risk and the household ability to respond to risk through the risk management strategies discussed above. Thus, Heitzman *et al.* (2002) decompose household vulnerability into a “risk chain” comprising (a) uncertain events, (b) the options for managing risks or risk responses and (c) the outcome in terms of welfare loss. Households face risks, that is, exposure to uncertain events. To contend with risks, households make use of a number of risk management options. Risks combined with responses lead to outcome. Thus a household is said to be vulnerable to the outcome of an uncertain event if it does not have sufficient resources to adequately contend with the outcome of the event. In other words, the extent to which a household is vulnerable to an uncertain event, and the extent to which the household can become and/or remain poor, depends on the size of the shock and how effective the household is in managing the uncertain event, both *ex-ante* and *ex-post*. For example, variability in climatic elements increases the vulnerability of rural livelihoods and reduces the ability of small-holder households to deal with risks, shocks and stresses (Assan *et al.,* 2009; Prowse, 2008). Prowse argues that the limited nature of assets of those in this category exposes them to further risk and lessens their ability to cope. Several households within this category are reported to employ non-farm diversification, on-farm diversification and migration as adaptive strategies (Ellis, 2000).

Various scholars have analysed vulnerability from different perspectives. First, Christiaensen and Subbarao (2004) and Chaudhuri *et al*. (2002) consider vulnerability as the probability of consumption falling below a poverty threshold. Ligon and Schechter (2003) consider vulnerability as low expected utility. Hoogeveen *et al.* (2004) provide guidelines for constructing vulnerability measures, and a review of the shortcomings of the measures developed until now. Fourth, Hoddinott and Quisumbing (2003) provide a more formalised survey of vulnerability together with the econometric methodology behind the currently developed measures. Fifth, Kurosaki (2006) reviews the quickly expanding literature on different vulnerability measures, favouring their use as advancing poverty measurement from a static to a dynamic framework. He argues for the usefulness of all for different policy purposes; thus the inability to choose an overall acceptable definition. Lastly, Tasokwa (2011) conceptualised vulnerability in the context of household food calorie consumption. She used the level of maize consumption and production as a proxy for vulnerability to food insecurity. Her explanation was that maize accounts for about 50 per cent of the calorie consumed among the Malawian households. Therefore, households that consumed less than 50 per cent of maize were considered to be vulnerable to food insecurity. Also, Kristjanson *et al.* (2002) and Thornton *et al.* (2006b) used income per adult equivalent as a proxy for household vulnerability to poverty. This approach derives the poverty measure on the basis of a household consumption basket of both food and non-food items that are considered to meet the basic needs of most Kenyans. By Kenyan standards, a rural poverty line is Kshs 1,239/AE/month.

In the sequel, this study follows the approach by Kristjanson *et al.* (2002) and Thornton *et al.* (2006b), where household income per adult equivalent is used as a proxy for vulnerability to food insecurity. This approach to vulnerability considers household income per adult equivalent as the dependent variable, which is determined by household and farm-based factors, and is subject to covariate or idiosyncratic risk factors. However, it is worth noting that the probability of becoming vulnerable tomorrow is impossible to measure, but the analysis of income and consumption dynamics and variability as proxies for vulnerability is possible. Overall, the expectation is that vulnerability is tied to income per adult equivalent as an outcome.

The current study makes the assumption that within comparable income levels per adult equivalent, there are factors that may increase the resilience of the households to extreme weather events such as drought or floods. Thus, household vulnerability to food insecurity at time t (VFI_t) can be defined as the probability that income per adult equivalent at period t denoted as Y_t, will fall below an *ex ante* defined income level (Y):

$VFI_t = Pr\ (Y_t \leq Y)$

It is also important to note that poverty, food security and vulnerability are interlinked. Poverty refers to lack of physical requirements, assets and income; while vulnerability focuses on the exposure to shocks, stress and risks, and on the lack of means to face the damage or loss. Poverty is a static concept, while vulnerability is dynamic, multi-dimensional, and a better concept for measuring change. Poverty contributes to vulnerability through three mechanisms: (a) the narrowing of coping and resistance strategies, (b) the loss of diversification and the restriction of entitlements, and (c) the lack of empowerment. On the other hand, achieving food security is amongst the most basic needs of any society and it is understood as a pre-requisite for development to occur (Nyariki and Wiggins, 1997). Given the inter linkages among vulnerability, food security and poverty, this study chooses to use income per adult equivalent as a proxy for vulnerability to food insecurity. Several indicators have been used to represent a number of variables to assess vulnerability to food insecurity in Kenya and at county level. These indicators and variables are discussed below.

ii. Defining the independent variables

In exploring more deeply the role of environmental resources in the livelihoods of the people, the concept of sustainable livelihood approach is adopted. The sustainable livelihoods framework emphasises five different assets upon which individuals draw in directly or indirectly to build their livelihoods. These assets can give rise to a flow of output, possibly becoming depleted as a consequence, or may be accumulated as a surplus to be invested in future productive activities. The independent variables are derived from the five types of capital: natural, social, physical, human and financial capital. These are farm-based and household related parameters.

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CHAPTER FIVE

THE IMPACT OF CLIMATE VARIABILITY AND ADAPTATION STRATEGIES IN THE SOUTHERN RANGELANDS OF KENYA

5.1. SUMMARY

This chapter discusses the impacts of climate variability and adaptation options in the southern rangelands of Kenya. It establishes the trends in climate factors such as rainfall, rain days and temperature in an attempt to understand climate variability and change in the study area. It compares the trends in rainfall, rain days and temperature in terms of monthly means, and minimum and maximum levels. The chapter also explores the climate extreme events that have occurred in the study area including their repercussions on the local economies. It goes further to shed light on the adaptation options that have been used by in different land-use systems to minimise weather related risks. Finally, it highlights innovative and transformative actions that have the potential to reduce vulnerability of households to extreme weather events in the study area.

5.2 INTRODUCTION

In the current study both terminologies of climate variability and change were used. Climate change is defined as any change in climate over time, whether due to natural variability or human activity (IPCC, 2007). On the other hand, climate variability refers to variations in the mean state and other statistics (such as standard deviations) of the climate on all temporal and spatial scales (IPCC, 2001). It captures year to year variations of climate elements such as rainfall and temperature at several time scales (Tasokwa, 2011; Wasonga, 2009). Variability includes more than individual weather events and may result from natural internal processes within the climate system (internal variability) or to variations in natural or anthropogenic external forces (external variability) (Tasokwa, 2011; World Bank, 2009; WWF, 2006). The underlying concept is that climate variability and change are both manifested at the community level; thus it is not possible to treat variability separately from climate change (Smit *et al.*, 2000; IPCC, 2001, 2007; Tasokwa, 2011). The data used and the time-frame considered only account for a change over a few decades, and could therefore well be variability or a phase of an oscillation (Hagebuck *et al.*, 2005). This study focuses on unravelling the mysteries of adaptation of rural households to climate variability and change.

Climate variability and change have a large influence on the livelihoods of communities in Kenya. The climate factors with the largest influence are rainfall and temperature. Rainfall is, however, the single most important element influencing the activities of southern rangeland communities who depend on rain-fed agriculture for their livelihood. Even though, man has lived with and experienced extreme climate events including disasters throughout the time of his existence. In the past, changes have been gradual providing adequate time for recovery as opposed to the present time, where climate related events have become more rampant, and have allowed no or limited time for recovery.

5.3 STUDY AREA

5.3.1 Kajiado County

Kajiado County has an area of 19,600 km^2 (CBS, 1981). Most of the county lies in the semi-arid and arid zones (zones V and VI). Only eight per cent of the county has potential for rain-fed cropping (zone IV) mostly found in the Athi-Kapiti Plains, close to Nairobi, and in the south of the county, along the Kilimanjaro foothills. Rainfall is bimodal with mean annual rainfall ranging between 300 to 800 mm. The short rains occur from October to December and long rains from March to May (ROK, 2009a; , ROK, 2002a). The distribution of rainfall between the two seasons changes gradually from east to west across the county. In eastern of the county more rain falls during the short rains and in the western part, more of rain falls during the long rains.

The economy of Kajiado County is still dominated by the Maasai, who are largely pastoralists, but rain-fed farming, largely carried out by non-Maasai, has thrived as a major economic activity in higher potential areas of the county (ROK, 2009a). Moreover, irrigated cropping has also increased along river valleys and in swampy areas. Irrigated cropping is practised along the Ngong Hills, Lolturesh River in Kimana, Kilimanjaro foothills and Namanga. Other economic activities include tourism in Amboseli National Park and mining of soda in Lake Magadi. The National Park is a major tourist attraction, but provides no revenue for the county and generates little employment for the local people. Similarly, the soda mine employs only 600 local people while most employees are immigrants from other counties.

5.3.2 Makueni County

Makueni County lies on Latitude 1º 35´ south and between Longitude 37º10´ east and 38º 30´. It borders Machakos County in the North, Kitui County in the East, Kajiado County in the West and Taita-Taveta in the South. The County covers an area of 7,965.8 km² and is approximately 250 kms from north to south and 100 kms wide in the north and to 20 kms wide in the south (ROK, 2009b; ROK, 2002b).

The rainfall pattern is bimodal with the long (but unreliable) rains coming in March to May and the more reliable short rains in October to December. From June to October is a long dry period, while January to March is a short one. The hilly parts of the county receive 800 to 1200 mm of rainfall per year. The rest of the county receives less rainfall at about 500 mm per annum. The temperature ranges are between 18^0C and 24^0C in the cold seasons and 24^0C to 33^0C in the hot days (ROK, 2009b). The high temperature experienced in the low-lying areas cause high evaporation. The county is characterised by extreme rainfall variability. Typically good seasons are interspersed with extremely dry seasons and variations in the onset of rainy seasons add to the difficulty of ensuring adequate food production.

The lower division of Kibwezi, Kambu and Kiboko receive little rainfall but has enormous potential for ranching. The northern part of the county is hilly with medium rainfall and has potential for food crop production, dairy, horticulture and coffee production. The parts of the county such as Kilungu, Kaiti, Kilome and Mbooni divisions have more of the planted trees than natural ones.

The altitude ranges from 600 m above sea level (a.s.l.) in the south to 1900 m in the west and north. The topography greatly influences the precipitation with the hill masses receiving higher amounts of rainfall. The mean temperatures in the county range from 20.2^0C to 24.6^0C but temperatures as high as 32^0C are often recorded during prolonged drought. The overall drainage pattern in the county is from west to east. There are a few permanent rivers and streams in the county. River Athi is the only major perennial river that drains the entire county. Mbooni and Kilungu Hills have a few perennial streams whose flow is extremely intermittent at low altitudes. Kibwezi, Kambu, Kiboko Rivers drain the lower areas of the county. Makueni County has a population of 884,527 people (ROK, 2009b) with an annual growth rate of 2.8 per cent (CBS, 2009).

5.4 METHODOLOGY

To understand the impacts of climate variability and change and the associated adaptation strategies in the study area, information was obtained from both primary and secondary data sources. Secondary data included literature review from government reports, publications, websites and other relevant documentation. These comprise daily precipitation and temperature data obtained from the meteorological sub-stations within the proximity of the study area (Makindu, Kibwezi, KEFRI, DWA and Kajiado Stations). At least a 30 year data set is recommended, the minimum needed for an accurate climate analysis for the tropics (Tasokwa, 2011; Wasonga, 2009; Stewart, 1998). The data were used to calculate annual rainfall, total rain days and mean annual temperatures. On the other hand, primary data were obtained through household questionnaire interviews, focus group discussions (FGDs) and direct observations. The information collected included household understanding of the evolution of climate extreme events and adaptation strategies.

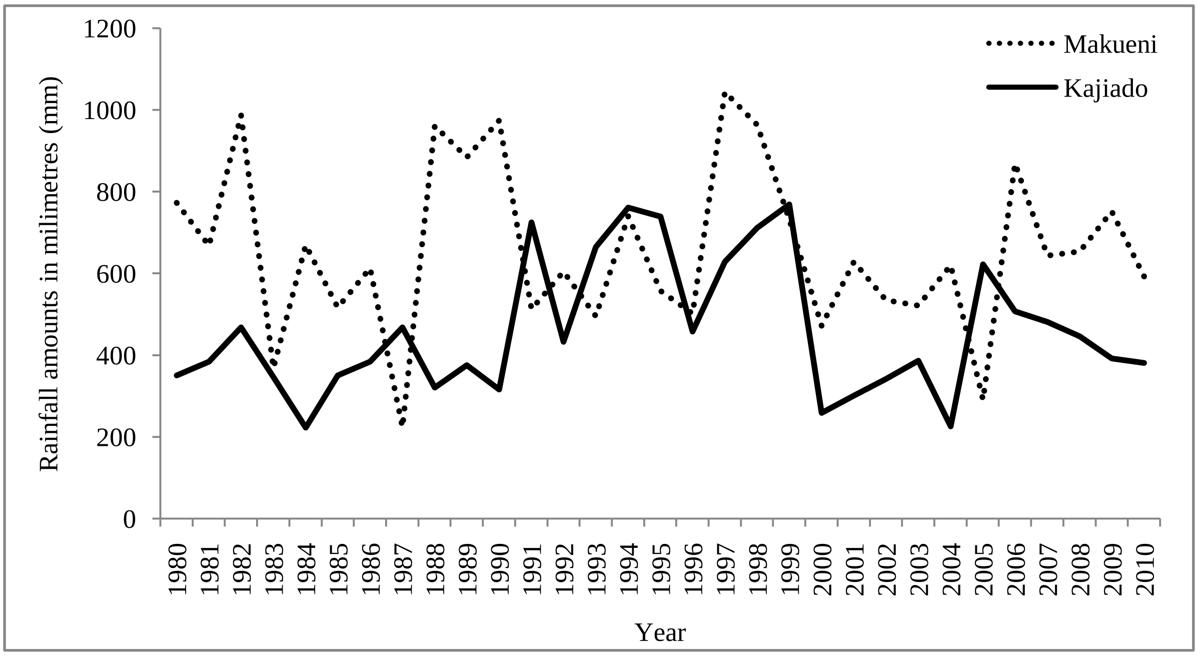
Questionnaires were administered to 198 households in Makueni (98) and Kajiado (100) Counties to solicit the communities' understanding of climate variability and change and their associated impacts on rural livelihoods. Also, two FDGs were held in Kajiado and Makueni Counties with selected individuals who were believed to be knowledgeable on the issues in question. The participants in FGDs were nominated through the help of the local administration (chiefs and the village leaders). Precautions were taken to ensure that all the different social groups and gender (such as women groups, youth organisations, the elderly and disabled) were represented. In order to allow freedom of expression, FGDs were conducted for different social groups and then one member of the group was selected to present the group deliberations in the plenary. This was followed by points of clarification, questions and suggestions to ensure a common understanding among the different social groups. The data obtained were analysed through descriptive statistics to obtain means, ranges, frequencies and percentages.

5.5 RESULTS AND DISCUSSION

Makueni County has four meteorological sub-stations, DWA, KEFRI, Kiboko and Makindu while Kajiado County has one meteorological station, Kajiado Station. In these stations the climate information collected includes rainfall, rain days and temperature. Thus, the three climate parameters for which more consistent data were available were used as proxies to determine climate variability and change. This was further supported by the fact that water is the most critical limiting factor in the ASALs. Therefore, the use of rainfall as the main climate parameter was appropriate.

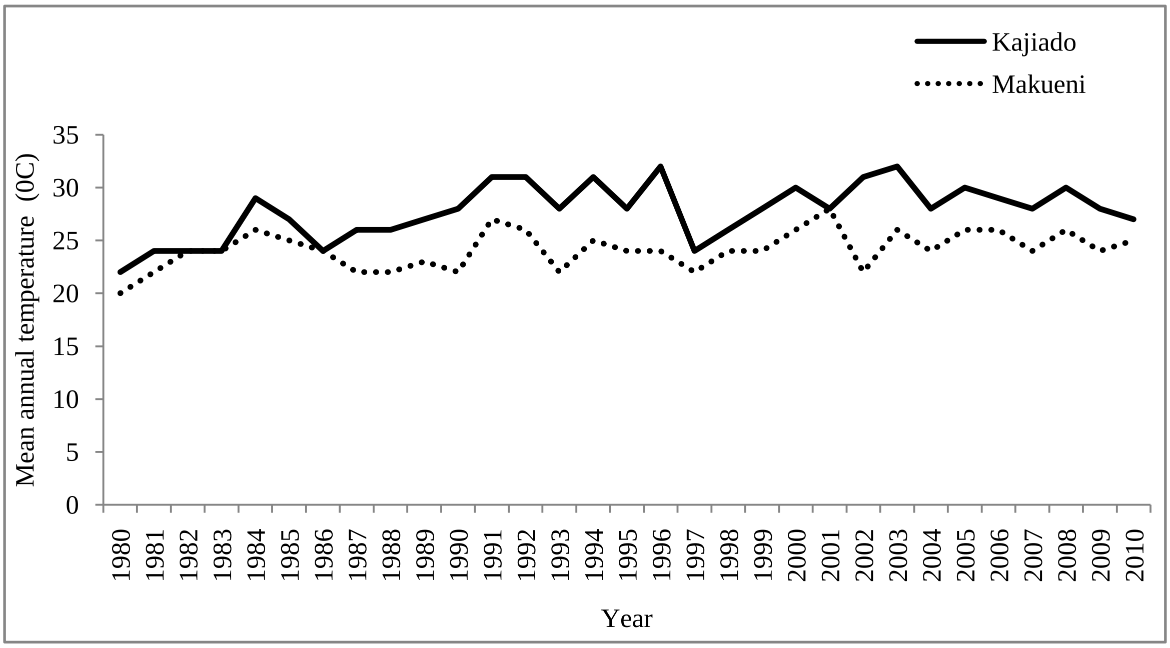
The mean annual rainfall, mean annual temperature and number of rain days varied between the two counties. Makueni County had more rainfall with a mean annual rainfall of 657.3 mm, a minimum of 223 mm and a maximum of 1,044 mm while Kajiado County had a mean annual rainfall of 458.9 mm, minimum 223 mm and maximum 769 mm. As a result, Makueni County was found to be wetter than Kajiado County. The trends in rainfall in the two counties are illustrated in Figure 5.1. Also, the temperatures in Kajiado County were higher than Makueni County (Figure 5.2). The former had a mean annual temperature of 27.8^{0}C with temperatures ranging between 22^{0}C and 32^{0}C. For Makueni County, the mean annual temperature was 24.2^{0}C with a range of 20^{0}C to 28^{0}C.

Figure 5.1: Annual rainfall for Kajiado and Makueni Counties from 1980 to 2010



Source of Data: Makindu, DWA, KEFRI, Kibiki and Kajiado Metereological Stations

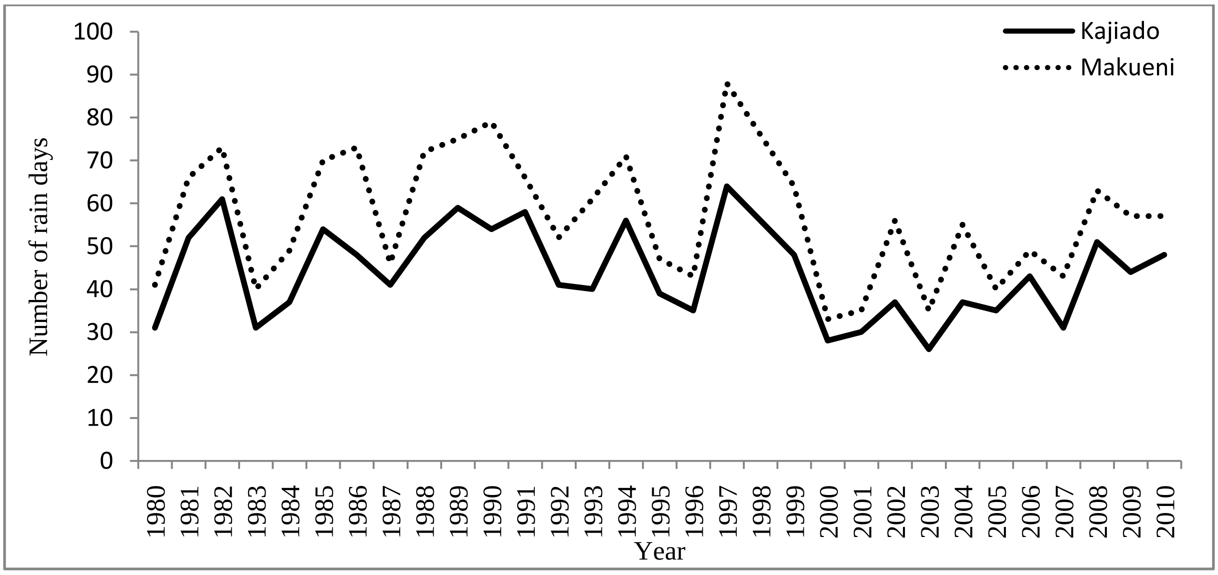
Figure 5.2: Kajiado and Makueni Counties from 1980 to 2010



Source of Data: Makindu, DWA, KEFRI, Makindu and Kajiado Metereological Stations.

The mean number of rain days for Kajiado and Makueni Counties is presented in Figure 5.3. The number of rain days showed a rugged and a more similar trend for both counties. Makueni County had an average of 57 rain days per year while Kajiado County had an average of 44 rain days per year. Rain days explains the distribution of rainfall over the rainy period and it influences level of crop and forage production. For example, rainfall distributed over more rain days tend to support better plant growth than those distributed in fewer rain days.

Figure 5.3: Mean number of rain days in Kajiado and Makueni Counties from 1980 to 2010



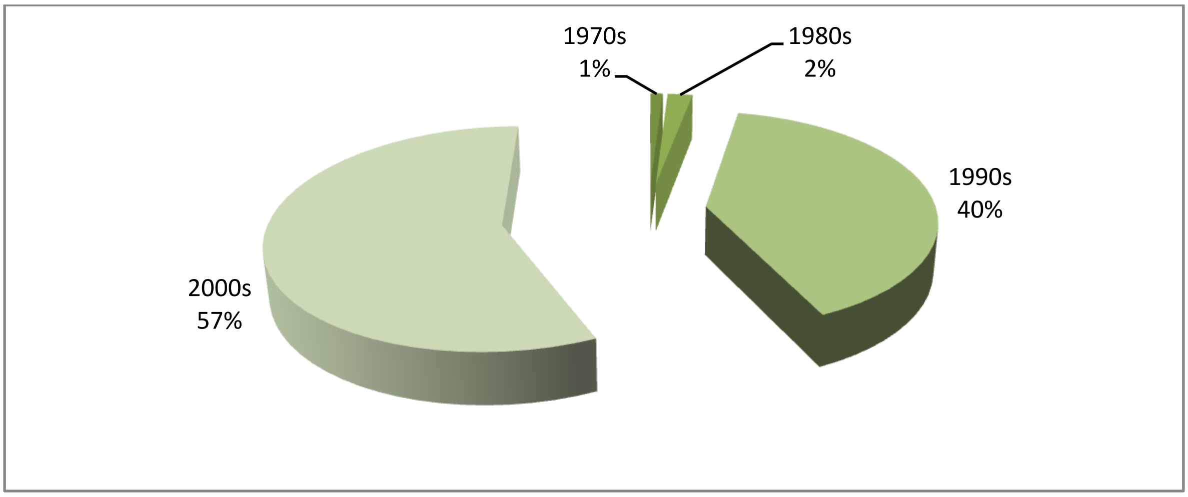
Source of Data: Makindu, DWA, KEFRI, Kibwezi and Kajiado Metereological Stations.

5.5.1 Impacts of Climate Variability in the Study Area

Climate related extreme events, including disasters, have over the years been a major concern to Kenya. These increasing natural and man-made calamities are imposing threats, suffering and loss of lives, and negative social, economic and environmental consequences working against the achievement of poverty eradication, economic growth and sustainable development. There have been numerous devastating extreme climate events in many parts of Kenya since the colonial period, and the recent droughts which struck the ASALs are reminders of one of the most pressing challenges of our times. These situations often disrupt the daily lives of the affected population and, as a result, basic necessities such as food, shelter, clothing and medical care are required to stabilize the situation.

The major incidences of disaster in the study area include droughts, floods, epidemics, fire, pests, diseases and conflicts. In recent times these disasters have caused disruptions in the economic and social development of the counties due to the inability to effectively cope with climate hazards. The main sources of vulnerability include poverty and development pressures including low economic growth, rising population pressures and unplanned urbanization. Other factors include fragile and degraded environments, epidemic diseases especially malaria and HIV/AIDS and poor governance. Drought is the most frequent and widespread climate related event in the country and the study area. The effects of droughts in Kenya are increasing exponentially and often lead to loss of livelihoods. The occurrences of drought and the number of people affected in Kenya, including Kajiado and Makueni Counties from 1971 to 2009 are shown in Figure 5.4 and Table 5.1.

Figure 5.4: Proportion of people affected by drought in Kenya from 1970s to 2000s



According to Orindi *et al.*, (2006) and Action Aid (2009), Kenya used to have regular droughts once every 10 years or so before the 1970s. In the 1970s, drought was experienced once every seven years, in the 1980s they came roughly once every five years, and in the 1990s once every two or three years. The current study establishes that since 2000, four major droughts have been reported in Kenya; 2000, 2004, 2006 and 2009. Now the drought occurs almost every year, especially in ASAL areas.

In a 31 year period (1980-2010), 15 extreme climate events have been reported across the country. About 53.3 per cent of these events have been widespread covering the whole country including Makueni and Kajiado Counties while the remaining (46.7 per cent) have been location-specific as shown in Table 5.2. Further, Table 5.2 shows that drought is the most frequent extreme climate event at the national level followed by floods, hailstone and landslide. However, drought has been the most widespread followed by floods while landslide and hailstone have been more location-specific. The distribution of climate extreme events that have occurred in the study area are shown in Tables 5.3 and 5.4 for Kajiado and Makueni Counties respectively.

Table 5.1: The occurrence of extreme climate events and number of people affected from mid 1980s to 2009 in Kenya

Year	Climate extreme	Area of coverage	People affected
2008	Hailstorm	Nyahururu	3,000
2007-09	Drought	Widespread*	10,000 000
2008	Hailstorm	Nyahururu	3,000
2004-06	Drought	Widespread	3,400,000
2003	Floods	Budalangi	28,000
2002	Land slide	Meru, Muranga and Nandi	2,000
1999/00	Drought	Widespread	4,400,000
1997/98	Floods (El Niño)	Widespread	1,500,000
1995/96	Drought	Widespread	1,400,000
1993	Drought	Widespread	1,200,000
1991/92	Drought	Arid/semi-arid zones	1,500,000
1985	Floods	Nyanza and Western	10,000
1983/84	Drought	Widespread	200,000
1982	Floods	Budalangi	10,000
1980	Drought	Widespread	40,000

***** Widespread means most of Kenya, including Kajiado and Makueni Counties

Source: Adapted from Orindi *et al.* (2006); Oxfam International (2006); ICPAC (2007).

Table 5.2: Distribution of extreme climate events in Kenya based on coverage

Climate extreme event	National	Southern rangelands and other ASALs	Other Kenyan regions
Drought	7	18	1
Hailstone	0	1	2
Landslide	0	0	1
Floods	1	6	3
Afflatoxin	0	1	0
Total	8	25	7

Table 5.3: Extreme climate events in Kajiado County

Year	Event	Impacts on livelihoods
1980	Drought	People starved because there was no food to buy
1981	Drought	People starved and livestock died and people looked for casual labour for the first time.
1983	Drought	Livestock had no enough sufficient grazing, and some died and households did not have enough milk for their families.
1984	Drought	East Coast Fever (Oldikana) outbreak, thus great losses in livestock; diversification from pastoralism to irrigated agriculture mainly maize and vegetables. Maasai given food aid inform of yellow maize and cooking fat
1990	Drought	Maasai women started small scale hawking of agricultural produce (beans and potatoes) to supplement household income and basic needs.
1991	Drought	Livestock had no enough sufficient grazing, and some died.
1994-96	Drought	Livestock taken up to Nairobi for the first time for pasture and water
1998	Heavy rains named *El nino*	Many gullies formed; Livestock suffered from bloat and bumper harvest in maize was realized while Wheat farms destroyed
2000	Drought and famine	Maasai given food aid inform of yellow maize, cooking fat and beans
2004-06	Drought	Livestock and wildlife died in large numbers
2005	Drought and famine	Livestock and wildlife died in large numbers Maasai moved with their cattle to Gilgil and Nakuru areas to graze.
2009	Drought	Livestock and wildlife died in large numbers. People moved with their livestock to Tanzania and came back after 6 months instead of the normal 3 months.

Table 5.4: Extreme climate events and their impacts in Makueni County

Year	Climate extreme event	Impacts on household livelihoods
1980	*Yua ya nikw'a ngwete*	People starved because they had money but there was no food to buy
1980-82	Drought and *Ndukabikwatiie* famine	Loss of livestock and increased deforestation to grow more crops. Also incidences of East Coast Fever.
1983	Drought and *Nikua ngwete* famine	Loss of livestock and government food aid maize and beans
1984	*Yua ya nyeki* (the drought of searching for forage)	Searching for forage and reduced number of cattle Supplementary feeding for severely undernourished children (<- 3 Z-scores)
1987	Heavy rains	High cotton yields and sufficient pasture
1990	Moderate rains	Influx of immigrants
1991-92	Drought and famine	
1991	Good rains and	Adequate food supply for the households and no limited movement with livestock
1994	Drought	East Coast Fever outbreak Reduced number of livestock
1997	*El-Niño* rains	Decrease in sheep and goat population due to blue tongue and foot rot
2003/2004	Outbreak of afflatoxin	Poisoning due to poor maize storage under damp conditions and loss of more than 100 lives
2005/2006	Drought and Famine	Livestock and wildlife died in large numbers, the Akamba moved with their cattle to Chyulu and Amboseli areas to graze.
2009	Drought and famine	Livestock and wildlife died in large numbers. People moved with their livestock to Chyulu and Amboseli areas to graze.

Source: Personal communication with local elders; www.fao.org/docrep/006/y5030e/.

Timeline data provided the historical background for Masimba and Mavindoni Communities (Table 5.3 and 5.4). Between 1980 and 2010, drought accounted for 78.6 per cent and 72.7 per cent of the extreme weather events in Masimba and Mavindoni Communities respectively. This confirms the frequency of the drought problem that besets southern rangelands and the pastoral communities.

Table 5.5 shows the frequency of extreme climate events that have been reported in Kajiado and Makueni Counties from 1980s to 2010. The extreme weather events were droughts, floods, and human and livestock diseases. The occurrence of the climate extremes in order of the most to the least frequent was drought (72 per cent), floods (24 per cent) and diseases (4 per cent). The livestock diseases associated with climatic extremes were East Coast Fever (ECF) during droughts, foot and mouth disease, and foot rot during flooding or heavy rains. Also, human diseases reported include small pox, diarrhoea and cholera.

Table 5.5: Extreme climate events in Makueni and Kajiado Counties from 1980 to 2010

Extreme climate event	**Kajiado County**	**Makueni County**
	Number reported	Number reported
Drought	11 (78.6)	8 (72.7)
Floods	2 (14.3)	2 (18.2)
Diseases	1 (7.1)	0 (0.0)
Afflatoxin	0 (0.0)	1 (9.1)
Total	14 (100.0)	11(100.0)

5.5.2 The Changes in Resources within the Study Area

The important resources and human activities in the study area included land, pasture, livestock, water and wildlife. These together with socio-economic activities such as education and human population have changed considerably over time. Pasture and water resources are believed to have declined over the last three decades. The possible explanation for decline in pasture and water resources from most to least important were increased droughts, deforestation and settlement leading to degradation of water catchment areas. Besides, the rapidly growing human population has led to increased demand for more agricultural land and settlement.

Livestock numbers have also changed considerably in both Kajiado and Makueni Counties. Kajiado County mainly inhabited by the Maasai had increased their herds from 1950s to 1980s. But with their integration into the modern economy, the Maasai have sold their animals and invested in other income generating activities. Besides, the frequent droughts, e.g. of 1984, 2000, 2003/2004, 2005, 2009 have led to considerable loss of livestock, demoralising the Maasai from restocking. Some of them have expanded their livelihoods to include farming, petty trade and casual labour so as to improve their household income. These, coupled with individualisation of land, have led to more and more of the dry season areas being converted to agricultural land. Similar findings have been reported by Amwata (2004) among the transhumant pastoralists of Imbirikani Location of Kajiado County.

5.5.3 Seasonal Calendars for Kajiado and Makueni Counties

A seasonal calendar shows the interaction of different land-use practices, rainfall seasons and household socio-economic activities on annual basis. The calendar of events for Makueni and Kajiado Counties are shown in Tables 5.6 and 5.7.

Table 5.6: Seasonal calendar for a community in Makueni County

Activity	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Rainfall	Short dry season		Long rain season		Long dry season				Short rainy season			
Land preparation												
Digging wells												
First weeding												
Second weeding												
Harvesting												
Dry planting												
Making bricks												
Terracing												
Grazing	Chyulu	Chyulu	Makueni			Mt. Kilimanjaro			Makueni			
Labour in schools												
Marketing												
Social groups (merry go round)												
Food situation	Adequate	Mild	Extreme shortage		Adequate				Mild		Adequate	

Table 5.6 shows that rainfall is fundamental for planning different land-use activities among the Akamba community in Makueni County. For example, land preparation, terracing and digging of wells was carried out January-March and July-September. These are periods just before the onset of the short and long rains. For the Maasai of Kajiado County, labour prices were lowest during the periods of short and long rains. The likely explanation is that during

rainy periods, pasture and water are adequate; hence labour requirement for herding is minimal, leading to low labour prices.

Table 5.7: Seasonal calendar for Kajiado County

Month	January	February	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Rainfall	Short dry season		Long rains *(Ingukwa)* (unreliable)			Long dry season					Short rains (*Oltumuret)* *(*reliable*)*	
Planting			Maize and Beans							Maize and beans		
Weeding												
Wildlife menace												
Livestock diseases	Anthrax Worms	Foot and Mouth		Malignant Catarrhal fever				Drenching				
water availability	Mild to moderate water search							Severe water search		Distilling water and dams		Circumcision
Human disease				Malaria								
Livestock grazing	Migration to wet season grazing areas						Migration to dry season grazing areas					
Livestock breeding						Mating in Sheep and goats						lambing and kidding
Harvesting	Maize Beans					Beans		Maize				Maize, beans
Labour Demand								Highest				
Labour Prices			Lowest								Lowest	
Food situation	Adequate	Mild shortage	Extreme shortage			Adequate				Mild shortage		Adequate

5.5.4 Climate Information and Knowledge

5.5.6.1 Traditional Knowledge

The rural communities have for many decades mastered the traditional indicators such as plants, animals, insects, birds, stars, the moon, wind, temperature, clouds and lightning patterns to predict weather conditions. According to Ogallo (2004), the Luos of former Nyanza Province and the Abaluhya of Western Kenya have traditional indicators to predict climate conditions. These communities do monitor the strength and direction of the wind, the frequency of a westerly driven swarm of insects, the position and direction of the movement of rain clouds and the plant phenological stage of development as indicators of seasonal rainfall performance. Ogallo (2004) noted that the frequency of water sprouts (twister) over Lake Victoria is a major indicator of seasonal rainfall performance. He further stated the involvement of the Abaluyha community in" rain making". Before they "make the rain," they study the wind, cloud patterns, conditions of some plant species and the behaviour of some snake species. Thus, the study reports that Abasuba communities of Mfangano Island, the Luos and Abaluhya had traditional methods of rainmaking.

The Akamba and Maasai community of Makueni and Kajiado Counties also have traditional knowledge on weather prediction. The weather indicators to predict the seasonal rainfall performance and onset include: wind direction; position of the sun; and associated shadows, plants, insects (bees in particular) and animals. The short rain falling between October to December is the most reliable and useful for land-use systems in the area. The traditional methods are still widely used among the rural communities, though the weather indicators vary from community to community, especially with to prominence of a specific indicator.

The traditional indicators may be categorised into two: living and non-living things. The living things indicators comprise of plants and/or trees (Table 5.8) in their different phenological stages of development, and the behaviour of animals such as bees, birds, frogs and livestock. Non-living indicators are common and they include sunset, clouds, lightning, heat or temperature, wind and dust devils; astronomical factors such as hill shadows and star clusters; and hydrological factors particularly streams/rivers. Of all these indicators, plants were the most commonly used due to their predictability and accuracy.

Table 5.8: Vegetation related indicators in the study area

Botanical name	Plant or tree phenological stages and rainfall prediction

Adansonia digitata	Trees in full bloom
	Short rains are 14-21 days away
Acacia mellifera	Flowering and blooming; the flowers shed by rain
	Short or long rains will fall in less than 15 days
Nagal atumia	Appearance of fruits
	Short rains would fall in less than 15 weeks
Asparagus Africana	Burst of flowers followed by fruits
	Short rains would fall in the less than five days
Commiphora	Full bloom
	Short or long rains would fall in one to two weeks time
Ficus sycomorus	Full bloom
	Short or long rains would fall in one to two weeks time
Acacia tortilis	Blooming with flowers
	Blooming without flowers
	Long rains one week away
	Short rains would fall in the coming two weeks
Melia volkensii	Blooms, flowers and small fruits appear
	Short rains in the next one week
Boophone disticha	Pink flowers drop
	Shot rains would fall in less than two weeks
Combretum apic	Blooms, flowers and small fruits appear
	Shot rains would fall in one to two weeks time
'Kititiu'	Blooms and flower buds appear. Flowers drop by rain
	Shot rains would fall in one to two weeks time
Dalbergia melanoxylon	Flower buds appear, blooming starts and flowers drop with rains
	Shot rains would fall in one to two weeks time
Ficus Thonningii	Full bloom
	Shot rains would fall in one to two weeks time
Ficus vasta	Full bloom
	Shot rains would fall in one to 2twoweeks time
Ficus ingens	After full bloom, the colour changes from pink to light brown
	Shot rains would fall in one to three days time

Source: Adapted from Ogallo (2004); Personal discussions with key informants.

Other indicators that were noted but were not explored in detail given the low importance and uncertainties attached to them by the two communities were:

1. Heat/temperature: The intense heat that is often abnormally higher than what is experienced in the rest of the days is an indication that the rains would fall in less than three days.

2. Lightening: Sighting of lightening at Ngundi Mwita on the Yatta Plateau indicates it would rain in less than two days.
3. Winds: Wind blowing in a north-easterly direction indicates the quality of rain. Backing of wind early in the season indicates a good rainy season.
4. Animal behaviour: Observing restless and running all over of animals indicates that it would rain in two to three days. Also, the animal dung indicates when it would rain. For example, very hard dung from cattle indicates it would rain in one week.

5.5.6.2 Seasonal Forecasts

Seasonal forecasts have the potential to help households plan and make decisions on appropriate land-use practices (ICPAC, 2007; Ogallo, 2004; Ziervogel, 2004). In the study area, households have a strong interest in receiving climate forecasts since their traditional systems of predicting rainfall and weather are generally unreliable. From FGDs, seasonal forecasts could help them adjust their management practices such as planting dates and selection of the most suited crop varieties. Besides, timeliness and reliability of climate information would enable households make more informed agricultural and non-agricultural decisions. Institutions such as the Meteorological Department and IGAD Climate Prediction and Application Centre (ICPAC) play a significant role in providing up to date information and in the format that is useable by the households in both counties. Other initiatives such as the Climate Outlook Forum (COF), organised annually by these organisations since 1998, have generated useful information that has potential to strengthen the adaptive capacity of the local communities (Ogallo, 2008). However, the seasonal forecast has not been widely used at household levels.

In the study area, nearly all the households (about 99.5 per cent) have access to weather information (Table 5.9), which comes from various sources. Approximately 42.2 per cent of the households received information from traditional observations and rain makers, followed by the media (39.9 per cent), meteorological stations (16.7 per cent), and market centres (0.5 per cent). The respondents receiving climate information from the various sources were asked if they had trust in the sources of information and if the information was useful in predicting future weather or climate. About 46.7 per cent indicated they trusted the sources of information, 43.3 per cent did not. The remaining 10 per cent were uncertain about the ability of the information sources to predict future climate.

On the timeliness of the weather related information (Table 5.10), the majority of households (64.6 per cent) indicated that information reaches them in good time regardless of the information source. However, about 31.3 per cent of the households indicated that the information was always delayed.

Table 5.9: Distribution of responses based on the source of weather information*

Information sources	Kajiado County	Makueni County	Total
Market centres	1(0.5)	0(0.0)	1(0.5)
Audio visuals	3(1.5)	1(0.5)	4(2.0)
Meteorological stations	2(1.0)	31(31.0)	33(16.7)
traditional observation	79(39.9)	5(5.0)	84(42.4)
Radio and traditional observation	1(0.5)	3(1.5)	4(2.0)
Radio	11(5.6)	39 (39.0)	50(25.3)
Television and radio	0 (0.0)	21(21.0)	21(10.6)
None	1(0.5)	0(0.0)	1(0.5)
Total	98(100.0)	100 (100.0)	198 (100.0)

*** Figures in brackets are percentages.**

Even though the majority of households received climate information, more than 80 per cent remarked that climate forecasts were not useful in helping them plan for their livelihood activities, particularly regarding the selection of crop varieties to be grown, grazing patterns and other alternative livelihood options. Moreover, these households claimed the climate information they received was in the form of general statements and failed to provide specific options on how to plan their land-use activities. It was noted that more than 70 per cent were willing to use the climate information if it was able to provide at least 50 per cent accurate predictions of the seasons in a year.

A similar study conducted in Machakos County in Kenya showed that more than 83 per cent of the farmers were willing to base their land-use decisions on seasonal forecasts if the predictions were correct in at least 3 out of 5 seasons. Their expectation on the level of accuracy in the prediction of seasonality was far much lower than the actual observed accuracy level of prediction of 80 per cent. In contrast, a study carried out on the Sahelian farmers showed that they were dissatisfied with the same level of accuracy due to the fact that they had only one growing season in a year, compared to the two in Machakos County (UNEP, 2006).

Table 5.10: Distribution of responses on the timeliness of climate information*

	Do you receive the weather information on time			
Responses	No	Yes	Sometimes	Total
Kajiado	48 (24.2)	42 (21.2)	8 (4.0)	98(49.5)
Makueni	14 (7.1)	86 (43.4)	0 (0.0)	100 (55.5)
Total	62 (31.3)	128(64.6)		

*** Figures in brackets are percentages**

5.5.5 Adaptation Strategies in the Study Area

The adaptation strategies used by various households differ depending on the seasonality and the extent of drought. The adaptation strategies among the households in Kajiado and Makueni Counties under drought conditions include digging of dams, splitting of livestock among friends and kins, pasture management, sale of livestock, digging of boreholes, use of drought tolerant livestock species, planting of drought tolerant crops, hiring more land for cultivation, petty trade and migration (Table 5.11). The adaptation strategies vary between Kajiado and Makueni Counties. For example, in Kajiado County, from the most to least preferred adaptation option was as follows: pasture management, splitting of livestock among friends and kins, migration, digging boreholes and keeping of drought tolerant livestock species. However, in Makueni County, the most preferred adaptation options were practising petty trade, planting drought tolerant crops, digging of dams, hiring more land for vegetables, migration and digging of boreholes in a descending order. Examples of drought tolerant crops grown in Kajiado and Makueni Counties include pigeon peas, cowpeas, *lab lab* and green grams. On the other hand, the drought tolerant livestock species kept in both counties include goats, donkeys and chicken.

According to the communities, if the rains were more than required in any given season, they would explore all possible options to maximise opportunities favouring heavy rains (Table 5.12). Similarly, in the case of total rain failure, households have devised adaptation strategies to cope with drought (Table 5.13). The adaptation options embraced by the respondents were based on the livelihood means available to them under various land-use systems.

Table 5.11: Households adaptation strategies to drought in the southern rangeland*

Type of adaptation strategies	Kajiado	Makueni

Digging of dams	2 (2.1)	13 (14.0)
Splitting livestock among friends	28(28.9)	1 (1.1)
Splitting animals and digging dams	5(5.2)	4 (4.3)
Digging boreholes, using drought tolerant livestock species	5(5.2)	5(5.4)
Planting drought tolerant crops	1(1.0)	20 (21.5)
Migration to other areas	27 (27.7)	10 (10.7)
Hiring more land for vegetables	0 (0.0)	10 (10.7)
Practising petty trade	0 (0.0)	26 (28.0)
Sale of livestock and donations	0 (0.0)	4 (4.3)
Pasture management	29 (29.9)	0 (0.0)
Total	97(100.0)	93 (48.9)

*** Figures in brackets are percentages.**

Table 5.12: Household response to heavy rains

Pure farmers	Agropastoralists	Semi-nomadic pastoralists
Plant longer maturing crop varieties	Plant water tolerant crops	Increase herd size
Harvest rain water for irrigation	Store pasture in form of hay	Venture into petty trade in the local centres since forage will be readily available
Increase farm sizes	Sell farm produce	Vaccinate animals against water related diseases such as foot rot.
Grow more horticultural crops	Plant longer maturing crop varieties	Construct *ndorotos (*dams) in readiness to store water
Obtain credit facilities to acquire more land to increase production	Ration food	Harvest forage and store as hay
Plant flood tolerant varieties	Diversification to alternative income generating activities	
Increase production of cash crops mainly horticulture	Sell grain stocks	
Acquire capital or loans to purchase inputs		
Sell grain stocks		

To the individual households, knowing whether rainfall would be above or below normal would not make the seasonal forecasts useful to them. They needed more information on weather to help them make informed decisions regarding their socio-economic activities (Table 5.14). In terms of ranking in the order of importance, both counties prioritised the need to have climate information at least six months in advance. For Makueni households, the second priority was land-use options, while information on diseases that affect livestock and crops was given the lowest priority. For Kajiado County, it was the reverse with livestock and crop diseases being given the second highest priority and the likelihood of dry spells being considered the lowest.

Table 5.13: Household adaptation to failure of rain in a season

Pure farmers	Agropastoralists	Semi-nomadic pastoralists
Drip irrigation for horticultural crops	Plant drought tolerant crop varieties	Migrate to dry season grazing areas such as Chyulu, Namaga and Mt Kilimanjaro
Plant drought tolerant crops	Diversification of livelihood options	Sell livestock before prices go down
Diversify to other income sources such as casual labour and petty trade	Petty trade and casual work	Keep animals that are drought tolerant
Ration food and reduce number of meals a day from three to two	Store grain stocks	Split livestock among kins and friends
	Plant early maturing or shorter duration crop Pure varieties	Store forage
	Plant more cereal crops mainly sorghum and millet	Increase the number of small stock (goats and sheep) that are resistant to drought
	Diversification to other income generating activities	Petty trade and casual work
	Implement soil and water conservation measures such as mulching	Ration food and reduce number of meals a day from three to two
	Ration food and reduce number of meals a day from three to two	
	Migration to town centres and cities	

Table 5.14: Distribution of responses on climate information needs in Kajiado and Makueni Counties*

Type of climate information needed by the households	Kajiado	Kibwezi	Total
Likelihood of dry spells	4(2.0)	12(6.1)	16(8.1)
Length of the rainy season	9(4.5)	5(2.5)	14(7.1)
Type of the rain(acid or storms)	9(4.5)	03(1.5)	12(6.1)
More than six months climate information	31(15.7)	40(20.2)	71(35.9)
Rainfall distribution behaviour for the season (onset and end)	12(6.1)	15(7.6)	27(13.6)
The most appropriate land-use options specific to the area	5(2.5)	23(11.6)	28(14.1)
The type of diseases that may affect crops and livestock	28(14.1)	2(1.0)	30(15.2)
Total	98(49.5)	100(50.5)	198(100.0)

***Figures in brackets are percentages**

From the focus group discussion, some of the impacts of droughts mentioned included water shortages for both domestic and livestock uses. Under normal conditions, only 10 per cent of the people use boreholes and the majority (75 per cent) use dams and pans while only 5 per cent accessing piped water (Table 5.15).

Table 5.15: Water sources and per cent of households depending on the source

Type of climatic condition	Boreholes and shallow wells	Dams and pans	Rivers and springs	Pipeline	Total
Normal	10	75	10	5	100
Mild drought	70	5	10	15	100
Severe drought	20	0	30	50	100

The access to different water sources changes with the severity of drought. As drought becomes more severe, more people obtain water from pipes and rivers that have more permanent water sources. Moreover, the distance to water points also varies depending on the seasonality and severity of drought (Table 5.16). Under normal conditions, the average distance to water sources was approximately 3 km. Under mild drought, distances to water sources were more than 5 km. The distances increase up to 15 km or more in severe drought conditions.

Table 5.16: Distances to water source (in km) and their relationship to climate conditions

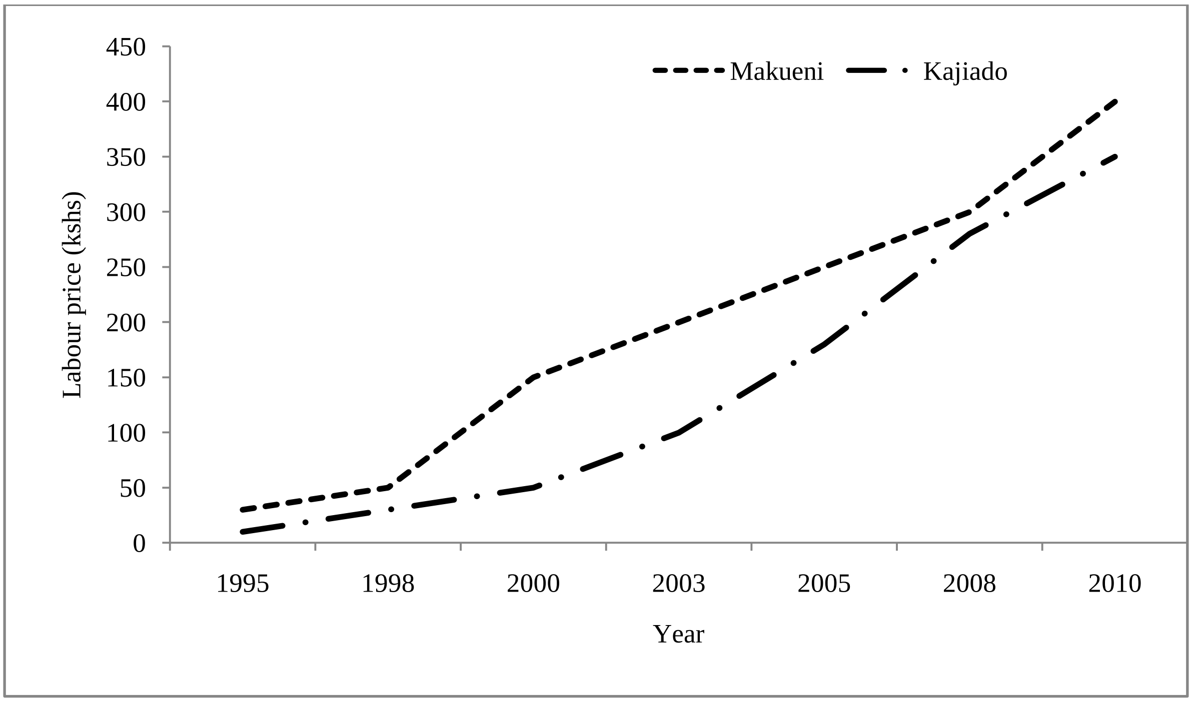
	Distance in km			
Type of weather condition	Boreholes and shallow wells	Dams and pans	Springs	Pipelines
Normal	3	3	3	3
Mild drought	6	8	0	0
Severe drought	15	0	15	15

Another aspect that was put into consideration was migration by the members of households either to the nearest trading centres or cities in search of 'greener pastures.' Most of the households had at least one of its members working away from home. As one of the local elders put it, "*the drought of 1984 was one of the worst, where most youths left the village to look for jobs, they have never come back, and the numbers keep on increasing"*. The elder elaborated that due to the emigration of the youth, the cost of labour has gone up from Kshs 30 per day in 1995 to Kshs 400 per day in 2010. Similarly, among the Maasai of Kajiado County, the price of herding labour has increased from Kshs 10 per day in 1990 to Kshs 350 in 2010 (Figure 5.5). This translates to an annual increase in labour price by 82.2 and 170 per cent for Makueni and Kajiado Counties respectively. The likely reason for this disparity in labour price is that in Makueni County, a majority of households were mixed farmers growing crops and livestock, thus increasing opportunities for the available labour, while in Kajiado County, households rarely paid for herding labour as children provided free labour.

However, with the introduction of free primary education, children have gone to school, causing labour scarcity and therefore resulting in increased labour prices.

On the other hand, given the vulnerability of the study area to extreme weather events such as drought, some household members move with their livestock to various areas and regions for sufficient grazing, i.e., pasture and water, depending on the severity of drought (Table 5.17). There is usually a disruption of socio-economic activities as a result of migration. The household socio-economic activities are often influenced by the prevailing weather conditions. For instance, under drought conditions, more than 60 per cent of household members aged between 10-45 years are always out in search of dry season grazing grounds. This age group comprises the children of school going age. Thus, school attendance is usually adversely affected, which makes children from this area unable to academically compete effectively with their counterparts from other counties.

Figure 5.5: Changes in labour prices in Makueni and Kajiado Counties (1995 to 2010)



Source of Data: Kajiado County Annual Report, 1995-2010; Makueni County Annual Report, 1995-2010).

Table 5.17: Migration pattern within the study area

County	Normal drought	Mild drought	Severe drought
Makueni	Yatta, Amboseli, Tsavo	National parks and reserves	
Kajiado	Surrounding group and	National parks and reserves	Namanga, Chyulu hills,

private ranches	Tanzania, Gilgil

5.6 CONCLUSION AND RECOMMENDATIONS

5.6.1 CONCLUSION

The impacts of climate variability and change are being felt across different levels, namely global, regional, national and local, including the southern rangelands of Kenya. In this area of Kenya, the impacts of climate variability and change include drought, floods, human and livestock diseases, and contamination of food through afflatoxin. In an attempt to mitigate these impacts, various adaptation strategies have been carried out under different land-use systems.

There are similarities on the adaptation options among the pure farmers, agropastoralists and transhumant pastoralists. Pure farmers refer to those who practise crop cultivation, and commonly irrigated agriculture. Agropastoralists are those who practise both crop and livestock production. The transhumant pastoralists keep livestock and occasionally grow a few crops along the river valleys. The adaptation similarities among these land-use systems include diversification to non-farm activities such as casual labour and petty trade, rationing of food and reduction of the number of meals a day from three meals to one meal a day, and migration to the nearest town centres and cities, as a last resort. However, there are also differences among the three land-use systems. Pure farmers have adapted by carrying out drip irrigation of horticultural crops and planting of drought tolerant crop varieties such as pigeon peas, green grams, sorghum and millet. The agropastoralists have coped with climate variability through planting of drought tolerant varieties, growing of high value crops such as sorghum and millet. In addition, they implement soil and water conservation measures and move with their livestock to dry season grazing areas. The households in Kajiado County, who are mainly livestock keepers migrate with their livestock to dry season grazing areas (Chyulu, Namanga and Mt. Kilimanjaro), where there are permanent water sources and pasture. They also sell their livestock before the prices go down, keep animals that are drought tolerant such as sheep and goats, split livestock among kins and friends, and store forage.

Climate information is a useful tool for minimising climate risks among the rural communities. Given the importance of information to the households, nearly all have access to it. Unfortunately, access does not necessarily mean usefulness. It was evident that the traditional methods of predicting weather parameters were still widely used in the study area and the indicators varied from community to community. For example, some of the traditional indicators to predict rainfall include the living and non-living things. Examples of living things include plants, insects and animals. The non-living indicators include sunset, clouds, lightening, heat, temperature, wind, dusts, and astronomical factors such as hill shadows, star clusters and hydrological balance. Among the many indicators, plants were commonly used due to their predictability and accuracy.

Other methods used to obtain climate information include media, meteorological stations and market centres in descending order of importance. Even though more than half of the households (64.6 per cent) received weather information on time, still the majority (80 per cent) felt the information was not useful in helping households make appropriate land-use decisions. Most households felt the information would be more useful if it was availed at least six months prior to the beginning of a season. They argued that the time period would give them enough time to acquire cash to buy necessary inputs for the proposed alternative land-use options. They also highlighted the need to package the weather information in a clear and understandable form or in a 'layman's language; and to recommend specific adaptation options that are best suited for each land-use system. Thus, up-scaling of best practices, especially the traditional climate prediction indicators, is fundamental. This calls for continuous mapping of different weather prediction indicators that have been proved to be effective and reliable for show-case and up-scaling. The communities were interested in working with the climate scientists through participatory workshops, seminars, field days to enhance collaboration.

Finally, given the role of climate in the ASALs, rainfall, rain days and temperature were used as parameters for climate variability and change. The study area has five meteorological stations namely Kiboko, DWA, KEFRI, Makindu and Kajiado, which have data gaps especially on other climate parameters such as humidity, evapotranspiration and wind. These were therefore not considered in the analysis. The government of Kenya should invest in strengthening and increasing the spread of meteorological stations to collect relevant climate data for sound decision making.

5.6.2 RECOMMENDATIONS

To address issues of climate variability and change and adaptation options in the southern rangelands of Kenya, the following are recommended:

1. The need to increase the spread and number of meteorological sub-stations within the ASAL counties and ensure that the major agro-ecological zones are represented. These meteorological stations need to be facilitated with the essential infrastructure (tools and equipment) to collect the required data. For instance, almost all the meteorological sub-stations, in the study area lacked facilities to collect data on wind, atmospheric pressure and humidity.

2. Education and awareness among farmers, climate scientists and other stakeholders on climate and non-climate information available and the sources. This could be achieved through continuous interaction of stakeholders through meetings, symposiums, exchange visits and workshops.

3. The need to repackage the weather information in a clear and understandable form, or in a layman's language and to recommend specific adaptation options that are best suited for each land-use system. Climate information needs to be based on action oriented proposals to enable households make relevant land-use decisions.

4. The need to review and document best practices in climate prediction taking into consideration traditional knowledge for show-case, up-scaling and dissemination. This calls for continuous mapping of different weather prediction indicators that have been proved effective and reliable by other communities as show-cases and for up-scaling. The communities in Kajiado and Makueni Counties were interested in working with the modern climate scientists through participatory workshops to enhance the collaboration.

5. The need to establish micro-industries within the ASALs to help reduce outmigration. This will ensure job opportunities for the communities and alternative livelihoods

during periods of weather extreme events such as drought. Besides, it will encourage human labour to remain in the ASALs to help in the region's development.

6. The need to strengthen the agricultural production value chain from production to marketing, processing and packaging. For example, livestock is a key resource in the ASALs, yet the processing industry is based in Nairobi, i.e., Kenya Meat Commission. It is fundamental the KMC have decentralised branches in selected ASAL counties to provide ready market for the livestock products.

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CHAPTER SIX

THE LINK BETWEEN CLIMATE VARIABILITY, LAND-USE AND LIVELIHOODS IN THE SOUTHERN RANGELANDS OF KENYA

6.1 SUMMARY

Kenya's southern rangelands are experiencing climate variability, especially with respect to rainfall. Rainfall is recognised as one of the critical parameters influencing land-use dynamics in the arid and semi-arid areas. Land-use is rapidly changing in terms of the type of livestock kept, crops grown and livelihood options. To understand how climate variability and change contribute to land-use change, questionnaire interviews, Focus Group Discussions and direct observations were used to obtain information from households in Kajiado and Makueni Counties. In addition, information was obtained from secondary sources such as government reports, previous studies and publications. The study found out that land-use activities vary across rainfall gradients and are some of the factors that determine if a household would diversify its farm and non-farm activities. Besides, rainfall influences the type of crops to be grown and the number and types of livestock kept by the households. Thus, holistic land-use management is a promising way of increasing resilience of households in the arid and semi-arid lands to climate risks and other vagaries.

6.2 INTRODUCTION

In Kenya, the arid and semi-arid lands (ASALs) constitute 80 per cent of the total land surface area (Nyariki and Ngugi, 2002; Amwata, 2004). The available data indicate that this region contains 30 per cent of the national population and 50 per cent of the national livestock population and vast amounts of untapped natural resources (ROK, 2004; UNDP, 2010). In terms of rainfall, the ASALs receive an annual precipitation of between 500 mm and 800 mm and lie within ecological zone 1V, with an extension to zone V. The traditional land-use in the area has been pastoralism, minimal agriculture and dry season grazing (Farah, 1996; Campbell and Migot-Adhola, 1981).The land-use is controlled by climate, soil, technology, markets and customs (Nderitu *et al.*, 1999).

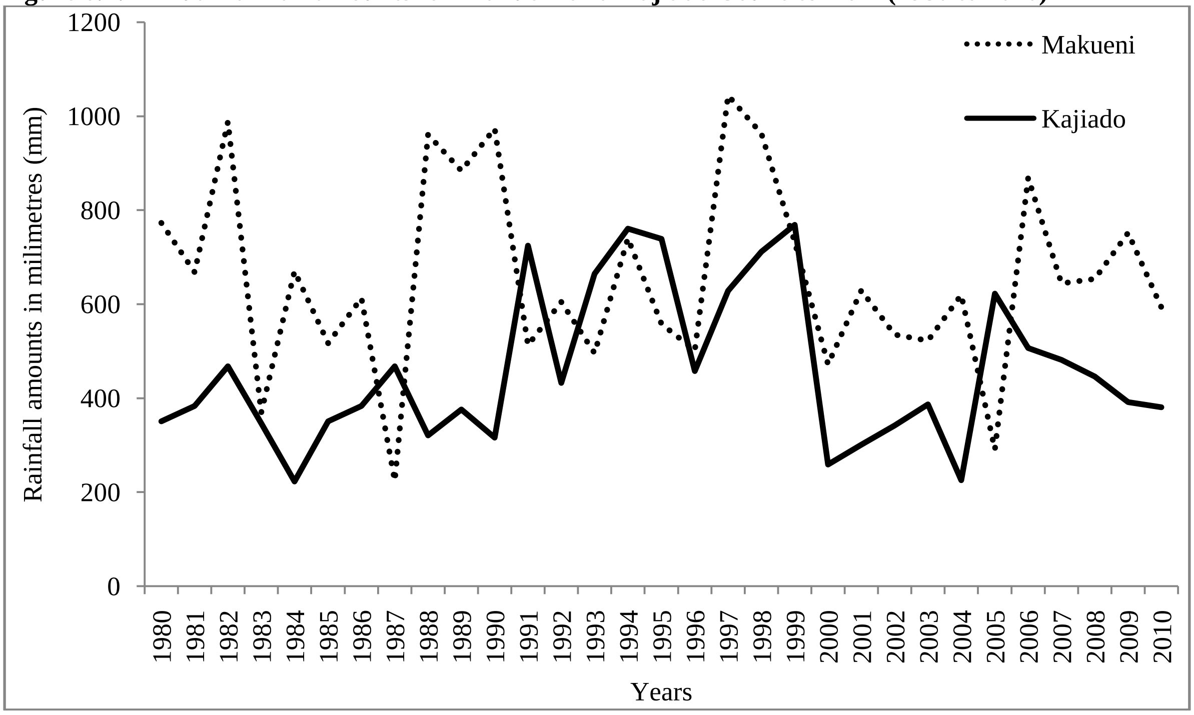
Even though other biophysical and socio-economic factors interact together to influence the ecosystems and livelihoods in the rangelands, rainfall has been given a lot of weight given that it is the most critical and limiting factor in the ASALs. Rainfall patterns in the rangelands have historically dictated spatio-temporal variability in water and fodder availability, influencing mobility and settlement patterns, and leading to the development of pastoralism as the more suitable livelihood (Swift, 1988, Fratkin *et al.*, 1999; Wasonga, 2009; Wasonga *et al.*, 2010).

While pastoralists have evolved their methods of managing these climate risks over time, increasing population pressure and more rapidly evolving socio-economic conditions (catalysed by increasing interaction with larger towns and cities) have began to erode the coping mechanisms. These evolving socio-economic issues have increased seasonal hunger by reducing livestock productivity and by causing a collapse in livestock prices as desperate herders try to dispose of emaciated animals. The relative terms of trade between livestock and grain have often rapidly turned against livestock during droughts (Wasonga *et al.*, 2010) making the purchase of grains and other commodities significantly more difficult for the affected households, thereby increasing their vulnerability to food insecurity.

Extreme weather events, primarily droughts with occasional flooding, are the most severe and common in the ASALs. In Kenya in general and southern rangelands in particular, drought has been reported as the most frequent extreme weather event. While Rass (2006) lists nine major droughts that have occurred in the last four decades in Africa (1965/66, 1972/74, 1981/84, 1986/87, 1991/92, 1994/95, 1999/2001 and 2005/06), Kenya lists about 13 such droughts, with 1981/84 being the worst not only in Kenya but also in the history of the Greater Horn of Africa (Orindi *et al.*, 2006). The present study notes that Makueni and Kajiado Counties have reported 11 and 14 droughts respectively within the same period.

The effect of rainfall variability on people living in the ASALs of Kenya is expected to be exacerbated by worsening climate variability and change. In Kajiado County, the mean annual rainfall from 1980 to 2010 was 460.6 mm (Figure 6.1), with a minimum, maximum and standard deviation of 223 mm, 761 mm and 170.34 mm respectively. Similarly, for Makueni County, the mean annual rainfall for the period 1980 to 2010 was 577.5 mm, with a minimum of 226 mm, a maximum of 1,034 mm and a standard deviation of 212.4 mm. The fluctuations in mean annual rainfall as depicted by peaks and troughs make planning of land-use activities difficult.

Figure 6.1: Annual rainfall amounts for Makueni and Kajiado Counties from (1980 to 2010)



Source of Data: Kajiado, DWA, KEFRI and Makindu Meteorological Stations.

According to Focus Group Discussion and household surveys, 11 and 14 extreme weather events for Makueni and Kajiado County respectively have been reported from 1980 to 2010. For both counties, droughts occurred in 1983/1985, 1993/1994 and 2005 while heavy rains were reported in 1986/87 and 1997/1998. The drought events coincide with the lowest annual rainfall recorded in the Makueni meteorological stations. Similarly, in Kajiado County, social surveys established that droughts were experienced in 1984, 1990, 1991, 1994, 1996, 2005 and 2006. This coincides with the data from the Kajiado meteorological station, where drought was recorded in periods of lowest annual rainfall as depicted by the troughs in Figure 6.1. Heavy rains were recorded in 1997/1998.

Already, the annual rainfall is varied with distinct low and high amounts, and given the trend of global warming, it is expected that weather patterns will be altered, especially rainfall amounts, resulting in increased severity and frequency of extreme climatic events. It has been argued that the effects of climate variability and change will probably be most acute for pastoralists and agropastoralists, especially those in Africa, including Kenya (Wasonga *et al.*, 2010). Climate risks interact with other stresses such as diseases, changing land tenure, sedentarising populations, increasing banditry, consequently promoting a vicious cycle of poverty. For pastoral populations, this scenario is aggravated by their low adaptive capacity, which, as opposed to more intensively managed systems, tends to evolve slowly in the face of change, thus increasing vulnerability to climate shock (Hulme *et al.,* 2001).

6.3 STUDY AREA

The study was conducted in Kajiado and Makueni Counties of the southern rangelands of Kenya. Southern rangelands refer to the arid and semi-arid counties found on the southern part of Kenya, and are characterised by low unreliable rainfall, infertile soils and high temperatures making these regions unsuitable for agriculture. From each county, eight locations were randomly selected, giving a total of sixteen locations and forms the two study sites.

6.3.1 Kajiado County

Kajiado County, formerly known as Kajiado District is located in the southern tip of the former Rift Valley Province between longitudes 36^0 5’ and 37^0 5’ east and between latitudes 1^0 0’ and 3º 0’ south (). The county borders Nakuru, Kiambu, and Nairobi Counties to the north, Machakos and Makueni Counties to the east, Taita-Taveta County to the southeast, Narok County to the west and northwest, and the Republic of Tanzania to the south and southwest. It covers an area of 19, 600 km^2 (CBS, 1981).

The county has two distinct rainy seasons; long and short rains that are influenced by altitude. The distribution of rainfall between the two seasons changes gradually from east to west across Kajiado County. In eastern Kajiado more rain falls during the short rains than during the "long rains". In western Kajiado most of the rain falls during the long rains. The mean annual rainfall ranges from 300 to 800 mm (ROK, 2009a). However, heavy rains occur around Ngong Hills, Chyulu Hills and Nguruman Escarpment, receiving 1,250 mm of rainfall per annum, and Magadi, receiving less than 500 mm of rainfall per annum (Berger, 1993). The analysis of rainfall for the two wet seasons indicates that most areas receive 50 per cent of annual rainfall during the March to May period and 30 per cent during the October to December period. Temperatures range from a minimum of 12°C to a maximum of 27°C (ROK, 2009a).

The county has 173,464 households and a population of 687,312, of which 50.2 per cent are male and 49.8 per cent female. The county has an annual population growth rate of 4.51 per cent and a population density of 31 people per km^2. In terms of age distribution, individuals between 0-14 years constitute 41.6 per cent), 15-64 years 56.1 per cent, and over 65 years, 2.3 per cent (CBS, 2009). The county is dominated by semi-nomadic pastoralists, the Maasai, who have been practising transhumance as their traditional mode of life under communal land ownership. However, this lifestyle has undergone transitional changes due to land reforms particularly adjudication and sub-divisions, which have seen the emergence of individual or private land ownership. Besides, the privatisation of tenure has promoted land sales thus opening up the pastoral ancestral land to immigrants from high potential areas, especially the farming communities from the neighbouring counties and even from other parts of the country.

6.3.2 Makueni County

Makueni County is located in the southern eastern part of Kenya between latitude 1°35′S and longitude 37°10′ and 38°30′E. It borders Kitui to the east, Taita-Taveta to the south, Kajiado to the west and Machakos to the north. Temperature in the county range from a minimum of 12ºC to a maximum of 28ºC and rainfall ranges from 150 mm to 650 mm per annum (Gichohi, 2000a). The county has bimodal rainfall pattern with the long rains falling between March and May and the short rains between October and December.

The county has a population of 884,527 with a growth rate of 2.8 per cent (CBS, 2009; ROK, 2009b). The population is composed of 49 per cent male and 51 per cent female. The age distribution in the county is 0-14 years (43.7 per cent), 15-64 years (51.1 per cent), 65+ years (5.2 per cent). Total number of households is 186,478 with a population density of 100.4 people per km^2. The population living below the poverty line is 34 per cent and 67 per cent of urban and rural population respectively (CBS, 2009).

Resources found in the county consist of forests, wildlife, minerals, building sand, water (rivers), pasture and land. The main economic activities are subsistence agriculture, beekeeping, small-scale trade, dairy farming and limited coffee growing; Ecotourism; Commercial businesses, Agricultural products comprise of fruits (mangoes, paw paws, watermelons), maize, cowpeas, beans, pigeon peas and lentils, livestock keeping and dairy farming.

6.4 METHODOLOGY

To understand the interaction of climate variability and land-use change, a study was conducted in Kajiado and Makueni Counties. Purposive sampling was first carried out to select the two ASAL counties based on whether they were mainly occupied by pastoralists or agropastoralists and similarities in terms of ecological zones. In addition, the researcher had prior information and experience in the two counties, which was seen as an advantage in understanding the problem in question. All the locations within the two counties were listed and eight locations were chosen randomly from each of the county. In Kajiado County, Loodikilani, Nkoile, Enkaroni, Enkorika, Olobelbel, Osilalei, Oloontulugum and Mashuru were chosen. In Makueni County, Kiboko, Nguumo, Masongeleni, Kambu, Mtito Andei and Makindu and Kikumbulyu were selected.

Both primary and secondary data were collected. The primary data were collected through household surveys, direct observations and interviews. Information on land-use and ownership was obtained through household questionnaire interviews and Focus Group Discussions (FGD) with selected group of individuals who were believed to have a wealth of knowledge on the study area. From the household surveys, the questionnaires addressed issues on household land-use changes along the rainfall gradient and livelihood zones, household characteristics such as land size and perceptions on climate variability and land-use changes. To establish the interaction of rainfall and socio-economic activities, households were mapped and geo-referenced using a global positioning system (GPS). GPS coordinates were recorded and plotted on agro-ecological zones maps to estimate rainfall levels experienced by each household. The rainfall levels obtained were categorised into two; those receiving less than 450 mm and those receiving more than 450 mm of rainfall. In addition, secondary data were collected from the Republic of Kenya ministries such as Lands, Livestock and Fisheries, Agriculture, Environment and Mineral Resources Ministries for both Kajiado and Makueni Counties. Publications and scientific reports supplemented the information from household surveys and focus group discussion.

6.5 RESULTS AND DISCUSSION

6.5.1 Climate Variability and Water Sources in the Study area

The water sources in Kajiado County were mainly boreholes, shallow wells, dams and pans. Whether a household uses a source of water depends entirely on rainfall. For instance, under conditions considered normal, the area receives at least 60 per cent of annual rainfall (Ndathi *et al,* 2011a), and households tend to use the dams and pans. As weather condition becomes severe, the dams and pans dry-up and households start to fetch water from the boreholes and shallow wells. However, the reliability of shallow wells for water is diminishing due to their proximity to the boreholes. In Kajiado County, only two boreholes were functional. The sources of water for the households under different climatic conditions is shown in Table 6.1

Table 6.1: Water sources for the households depending on the climatic conditions

Weather conditions	Boreholes and shallow well (per cent)	Dams and pans (per cent)	Rivers and springs (per cent)	Pipeline and tanks (per cent)	Total (per cent
Normal	10	75	10	5	100
Mild drought	20	0	30	50	100
Severe drought	70	5	10	15	100

Under normal conditions (when annual rainfall is at least 60 per cent reliable), majority of the households (75 per cent) obtain water from dams and pans, and, at this time, very few households use shallow wells and boreholes. In contrast, under severe drought, 70 per cent of the households use boreholes and shallow wells while the remaining 30 per cent use dams, pans, rivers, springs and piped water.

6.5.2 Link between Climate Variability and Land Size

Land ownership in the study area falls into three classes, communal land, trust land and individual land. From the questionnaire interviews, 60.5 per cent owned land individually and title deeds have already been issued. About 37.5 per cent of the households still own land communally or as group ranches, of which more than 50 per cent of these households are in the process of sub-division while only 1.7 per cent were tenants. Most of the privately owned lands were found in Makueni County. The average land holding per household for the study area is presented in Table 6.2. The overall mean land size for the study area was 110 acres; however the mean land sizes varied between Kajiado and Makueni Counties. In Kajiado County, the mean land size was 110 acres and that of Makueni was 17.63 acres. The large tracts of land in Kajiado County were found in the agro-ecological zone V and VI, or lowlands. These zones are unable to support farming activities due to their aridity, and consequently limited incentives for sub-division. Moreover, these households are predominantly livestock keepers, thus large tracts of land provide forage resources to the animals. The reverse was noted in Makueni County where land sizes were relatively smaller compared to Kajiado County. The likely explanation is that Makueni County falls in AEZ IV and V, which have potentials for agriculture, thus people have incentives to sub-divide land for agricultural intensification.

Table 6.2: Relationship between rainfall and land size in the study area

Land size	Kajiado		Makueni		Total
	>450 to >900 mm (semi-arid)	<300 to ≤450 mm (arid)	>450 to >900 mm (semi-arid)	<300-≤450 mm (arid)	
≤10 acres	0	4	51	7	62
>10 to ≤ 20acreas	0	0	1	24	24
>20 to ≤50acres	0	1	12	1	14
> 50 acres	0	93	0	4	97
Total	0	98	64	36	198

Table 6.2 shows the relationship between rainfall amounts and land sizes owned by the households. Climate variability is illustrated by variations in the amounts of rainfall received. In Kajiado County, all the households who owned more than 50 acres of land were found in areas receiving annual rainfall of between less than 300 and 450 mm (arid areas). In contrast, the majority of households in Makueni County (79.7 per cent) owned less than 10 acres and they were found in areas receiving rainfall of more than 450 mm (semi-arid areas). The probable reason for the disparity in land sizes is that in Makueni County, rainfall is slightly higher hence land has relatively higher agricultural potential and as a result, many immigrants flock the area to buy or rent land leading to locals dividing land to smaller sizes. Furthermore, as the household sizes increase, members are allocated individual parcels of land.

On the other hand, in Kajiado County, predominantly pastoral, rainfall is very low with lower agricultural potential, thus households have limited incentives to divide land, and therefore, land is still owned as a clan. On the same note, Ndathi *et al.* (2011b) noted that large tracks of land in pastoral households provide the privilege to practise mobility as a coping strategy for drought and the opportunity to maximise sparse forage resources in the ASALs. In addition, Almen (2000) reported that in coastal Kenya, rainfall gradient was among the factors influencing the population density and land sizes. He further stated that in livestock millet zone characterised by low rainfall, population density was very low, consequently big land sizes. As well, on the coastal plains with slightly more rainfall have high population density resulting in smaller land sizes. Likewise, Williamson and Sabbath (1982) established that environmental variables such as rainfall were the determinants of the land area owned in Marshall Islands, northern Pacific.

6.5.3 Relationship between Land-use activities and Rainfall in Kajiado and Makueni Counties

The major land-use activities in the study area varied between the Kajiado and Makueni Counties and were found to be linked to the amount of rainfall (Table 6.3). Generally, there are three livelihood zones in both counties; first livelihood zone is characterised by livestock keeping; second, marginal farming and lastly mixed farming. These are complemented by alternative livelihoods, charcoal burning, casual wages and, petty trade.

Table 6.3 shows that households in areas receiving low annual rainfall of less than or equal to 450 mm tend to have additional activities to supplement their household earnings in both Kajiado and Makueni Counties For instance, in Kajiado County, in addition to livestock keeping, the households practise off-farm activities such as charcoal burning and casual labour to boost their overall income. A similar observation has also been noted in Makueni County, where in addition to keeping livestock and crop cultivation, households in low rainfall areas also engage in non-farm activities. This finding is consistent with those of Little *et al.* (1999) which noted that in the lowlands of northern Kenya such as Marsabit, Moyale and Samburu, where average rainfall is low (below 400 mm), agricultural potential is very low, thus the region diversifies to non-farm activities such as wage labour and trading or business as a means of enhancing household wellbeing. Similar finding has been reported by Prah (1979) in Botswana, Webster (1979) in Malawi, Ezra and Gebre-Egziabher (2001) in Ethiopia, Deshingkar and Grimm (2004) in India, Mensah-Bonsu (2003) and Assan *et al.* (2009) in Ghana.

Table 6.3: Rainfall and land-use activities in the study area

County	Rainfall (mm)	Land-use activities
Kajiado	<300 to ≤ 450	Livestock keeping, charcoal burning and casual wages
	>450-900	Marginal mixed farming (livestock, maize, beans, fruits, vegetables, green grams)
Makueni	<300 to ≤450	Marginal mixed faming (livestock, maize, beans, fruits, vegetables, green grams), charcoal burning, petty trade and casual wages
	>450 to >900	Marginal mixed farming (livestock, maize, beans, pigeon peas)

Also, Rosenzweig and Wolpin (1993) noted that climate related events such as droughts and floods indirectly influence the behaviour of households by pushing them toward livelihood options such as petty trading, shop-keeping and other alternatives whose income streams are lower on average, but less volatile than pastoralism. Besides, Wasonga *et al.* (2010) and Carter and Barrett (2006) argue that even if drought occurred only once in several years, the very threat of this shock is sufficient to keep poor households trapped in poverty as they pursue lower-return livelihoods as an inefficient means of managing their risks *ex-ante*.

Another aspect of non-farm diversification that became prominent in the study area was migration. Climate variability (rainfall) has influence on migration. Households' surveys and key informant interviews reveal that some members of households migrate for non-farm opportunities elsewhere. According to one of the key informants in Makueni County, *Mzee* Mulee explained that in attempt to avert the impacts of increasing high temperatures and erratic rainfall, households in the study area have adopted migration within and outside the county as a coping mechanism. To Mr. Salao, a village elder in Kajiado County, 'the numbers of youths migrating during drought years are increasing. "My sons did not leave home in early 1990s, but since 2000, they have moved with their livestock and families almost every year due to poor rains. My two other sons work in Kajiado town as watchmen". There seems a negative relationship between migration and rainfall as revealed by the household survey and Focus Group Discussions. The survey showed that migration rates increased in years of low rainfall and severe droughts. From the surveys and FGDs, the years that were noted to have highest number of migration were 1984, 1988, 1998, 2000, 2003 and 2005. These years coincide with drought years reported in the Republic of Kenya

These observations are consistent with those of Waddington and Sabates-Wheeler (2003) who established that in resource poor areas; migration remains a last resort livelihood option and income source towards improvement in well-being. They further stated that where rural dry land communities are faced with risky environments, entire communities might follow circular migration routes. The perceived effect of low rainfall and drought on migration is very high, 74.3 per cent for Kajiado County and 62.3 per cent for Makueni County. Migration is employed as a survival and adaptive strategy against vulnerability to food insecurity associated with inadequate rainfall. The study also showed that more people migrate in drought years, and the year of first-migration for most of the respondents (58.9 per cent) coincided with those recorded by the Kenya Metrological Department as severe drought years in the southern rangelands of Kenya (climate, temperature and rain days data from 1965 to 2010).

Migration results in disruption of socio-economic activities. Households' socio-economic activities are often influenced by the prevailing weather conditions. For instance, under drought conditions, close to 61 per cent of households in Kajiado County and 26 per cent in Makueni County between 10 to 45 years migrate either in search of dry season grazing pastures or non-farm employment. This age group comprises children of school going age; thus adversely affecting school attendance. As a result, children from the ASALs cannot academically compete effectively with their counterparts from other parts of Kenya. Therefore, the government needs to work closely with the communities living in the ASALs to establish innovative and creative mechanisms to help minimise migration. Potential mechanisms include creation of micro-industries such as meat, milk and leather processing plants. These micro-industries would provide the much needed off-farm opportunities. In addition, mobile socio-amenities such as schools and health centres need to be provided to these communities. A good example is the mobile clinics and schools in Pokot and Turkana areas that have shown successes need to be replicated in other ASAL counties such as Makueni and Kajiado that are facing similar challenges.

6.5.4 Climate Variability and Livestock Numbers

Livestock is still a key resource in Kajiado and Makueni Counties and a major economic activity. However, livestock keeping is on the decline as a considerable number of households transform to agropastoralists. The growing commercialisation of the pastoral economy has encouraged livestock production for the market rather than pure subsistence. The major livestock types kept included cattle, sheep and goat, though other species such as donkey, pigs and camels are increasingly becoming popular due to the additional role they play. For example, the donkey provides transport for water during dry periods and products to markets for sale. Also, pigs have become an additional source of income as well as a way maximising refuse from the kitchen.

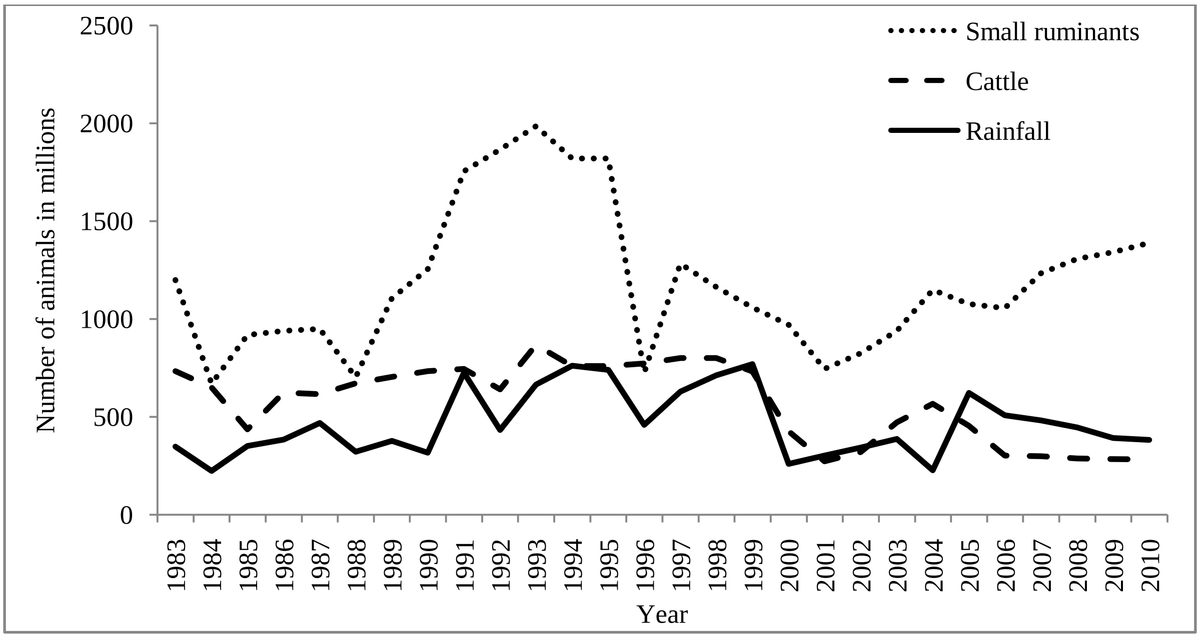
The production of the livestock sector is determined by rainfall levels, livestock population and pastoral dietary needs (Republic of Kenya (ROK), 1994). The long term trend of livestock population (mainly cattle, sheep and goats) in Kajiado County depicts variations with rainfall levels (Figure 6.2). The cattle population crash corresponds to periods of reduced rainfall amounts. These periods of cattle population decline match the years of drought as recorded in 1983-84, 1992-94 and 2000. The likely explanation for the close link between rainfall and cattle numbers is that cattle require a lot of feed and when rainfall are very high, more forage and water resource are available, thus households tend to keep more cattle to maximise the available resources. However, when rainfall is low and more unpredictable, forage resources become limited and households prefer to keep small ruminants such as sheep and goats since they have less feed requirements. Besides, goats are mixed feeders and would utilise a wide range of forage resources.

The trends in the number of small ruminants (sheep and goat) show discernable changes with rainfall levels (Figure 6.2). There is a negative relationship between rainfall and the number of small ruminants. Years that had high rainfall variations showed an increasing trend in small ruminants as shown in 1990, 1995, 2001 and 2004. The likely explanation for this trend is that when rainfall increases and shows a more predictable trend, more households tend to keep more cattle than small ruminants. But, when rainfall is low and shows high variability, households revert to keeping more of small ruminants due their ability to withstand very harsh environments. For example, considerable decline in small ruminant population (crash) was noted in 1984, 1987/1988, 1996 and 2001. These periods corresponds to periods of drought reported during the focus group discussion, household surveys and meteorological department annual reports.

Similarly in Makueni County, rainfall had a negative relationship with the number of small ruminants (Figure 6.3). The highest number of small ruminants was noted in periods of low rainfall amounts (1995, 2003 and 2005), while lowest small ruminant numbers were recorded in 1993, 1999 when rainfall amounts were at the highest. Furthermore, as mean annual rainfall becomes more varied, the numbers of the small ruminants have continued to rise from

1999 to 2006. The likely explanation is that the small ruminants are more adapted to harsh environment and can utilise the limited forage resources. In contrast, there was no relationship noted between rainfall and cattle numbers in Makueni County. The probable reason could be that households in the county have limited land size to keep large number of cattle due to their large dietary requirements; hence even under high rainfall, the households are unwilling to increase number of cattle kept due to limitation of land sizes.

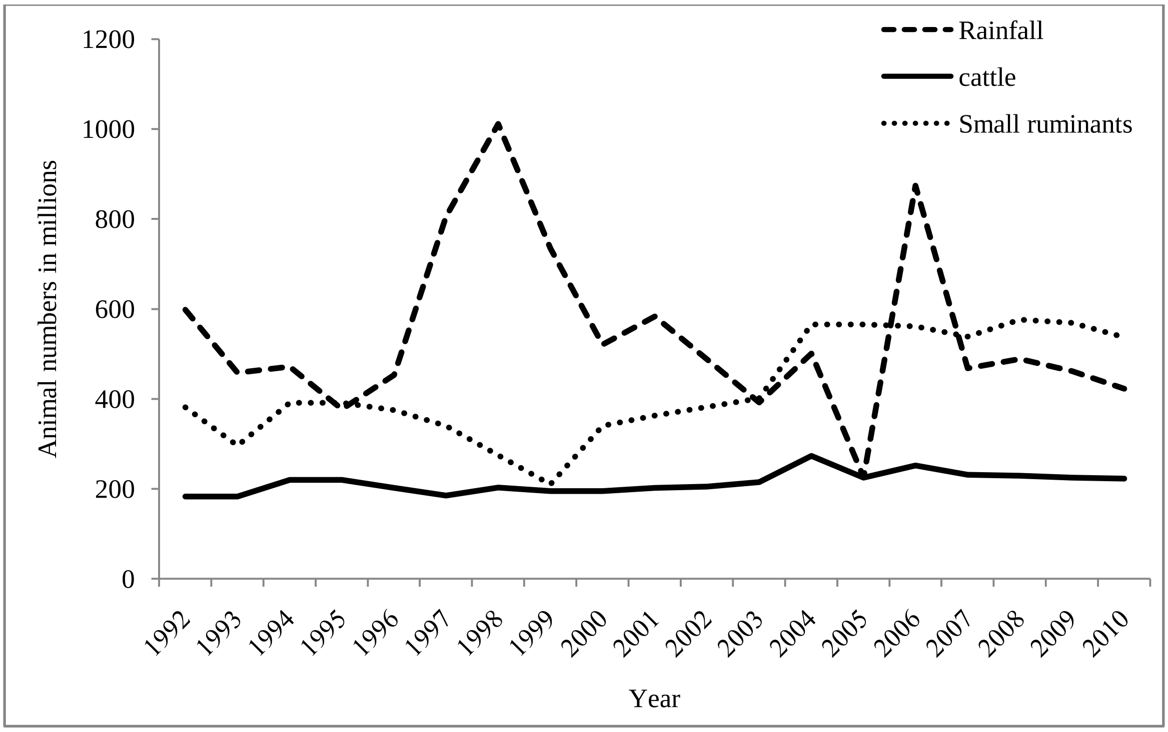
Figure 6.2: Linking rainfall and livestock numbers in Kajiado County



Source of Data: KIPPRA (2010).

In understanding the influence of rainfall on the number of livestock, it is necessary to show how rainfall also influences forage resources, which determines the number of livestock. Figure 6.4 shows that rainfall has no influence on pasture availability and stocking rate (animals/ha). The mean annual rainfall for the period 1991 to 2010 has been highly variable with distinct high and low levels. On the same note, the numbers of animals kept per hectare have been on the decline irrespective of the rainfall levels. Taking into account the fact that the productive and carrying capacity of land is crucial to support grazing, thus a clear indication of land is already over burdened. Therefore, even with high rainfall levels, the soils are unable to support adequate pasture growth. Another issue is the decline in land holding per household due to sales and privatisation of land tenure have considerably interfered with traditional grazing areas and resources, and subsequently fewer animals per unit area.

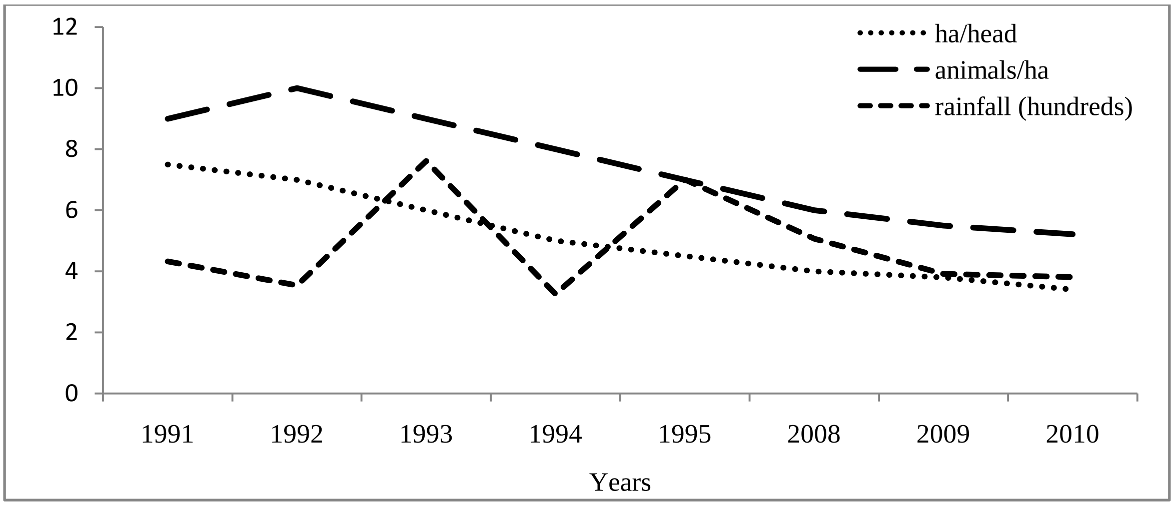
Figure 6.3: Relationship between rainfall and livestock numbers in Makueni County



Source of Data: KIPPRA (2010); Ministries of Agriculture and Livestock Development Annual Reports.

Despite the fact that the number of animals per unit area has decreased, focus group discussions still stress livestock mobility as useful strategy for both households in Kajiado and Makueni Counties to cope with drought at different time of the year (Table 6.4.). The households in Kajiado County move with their livestock as far as Mt. Kenya and Tanzania.

Figure 6.4: Relationship between rainfall and pasture availability in Kajiado County



Source of Data: Kajiado County Livestock Office Annual Report (2008; 2009; 2010); Kajiado, DWA, KEFRI and Makindu Meteorological Stations.

Table 6.4: Migration pattern for Kajiado and Makueni Counties

Counties	Normal drought	Moderate drought	Severe drought
Makueni	Yatta, Amboseli, Tsavo	National parks and reserves	
Kajiado	Surrounding group and private ranches	National parks and reserves	Namanga, Chyulu hills, Gilgil and Tanzania

Migration results in disruption of socio-economic activities. Moreover, household socio-economic activities and weather conditions are intertwined. Under drought conditions, more than 60 per cent of household members aged between 10-45 years were either out in search of dry season grazing grounds or job opportunities. This age group comprises the children of school going age; thus school attendance is adversely affected.

6.5.5 Climate Variability (Rainfall) and Crop Farming in the Study area

Growing of crops has become one of the livelihood strategies for the communities in the two counties of the study area. The crops that have persistently been grown in the study area include maize and beans and pigeon peas, which have been the main food crops. The crops grown in the study area can be classified into five:

1. Food crops: cereals (maize, sorghum and millet) and legumes (beans, cowpeas, pigeon peas and green grams);
2. Horticultural crops - *dudhi*, *karela*, *tuna*, french beans, brinjals, kale, cabbages, mangoes, citrus, papaws and bananas were grown under irrigation for subsistence and export;
3. Root crops: cassava and sweet potatoes;
4. Industrial crops: coffee, cotton and wattle trees; and
5. Oil crops: castor, macadamia and sunflower

The numbers of crops grown have evolved with some new crops being introduced and old ones being abandoned. Although various crops were being grown in the county, their successes depend on the reliability and the distribution of rainfall. Crop farming is mostly subsistence-oriented but occasionally the produce is sold to purchase basic needs and wants. The types of crops grown depend on the rainfall levels and the agro-ecological zones (AEZ) (Table 6.5). From Table 6.5, maize, beans and pigeon peas are the most common crops in both agro-ecological zones. This is because they are a staple food for the study area and also in most parts Kenya. The amount of rainfall influences the type of crops grown. For example, cotton is only grown in the semi-arid areas while cereals such as cassava, sorghum and millet and fruit trees are increasingly being grown in the low rainfall areas or arid areas because of their drought tolerance. Also, FGD reported that rainfall was diminishing and becoming more unreliable. As a result, coffee is increasingly being replaced by drought tolerant root crops such as cassava, millet and sorghum. For instance, some households in Kibwezi were abandoning coffee in semi-arid areas, due to its high rainfall requirement. Also in this county, a few households use parts of their yard for horticulture which boosts household food production.

A phenomenon that is also spreading quickly, especially around the larger towns in the area, is the construction of greenhouses made of a combination of mud, wooden bars, and plastic covers. The products are sold in the nearby towns while also lengthening the season during which a household has access to fresh vegetables, tomatoes and fruits, consequently enhancing vitamin intake. For Kajiado County, cropping is slowly picking up and most of crops grown were retained, and in addition, fruits and vegetables were introduced to diversify the households' food sources.

Table 6.5: Relationship between the different types of crops and rainfall amounts

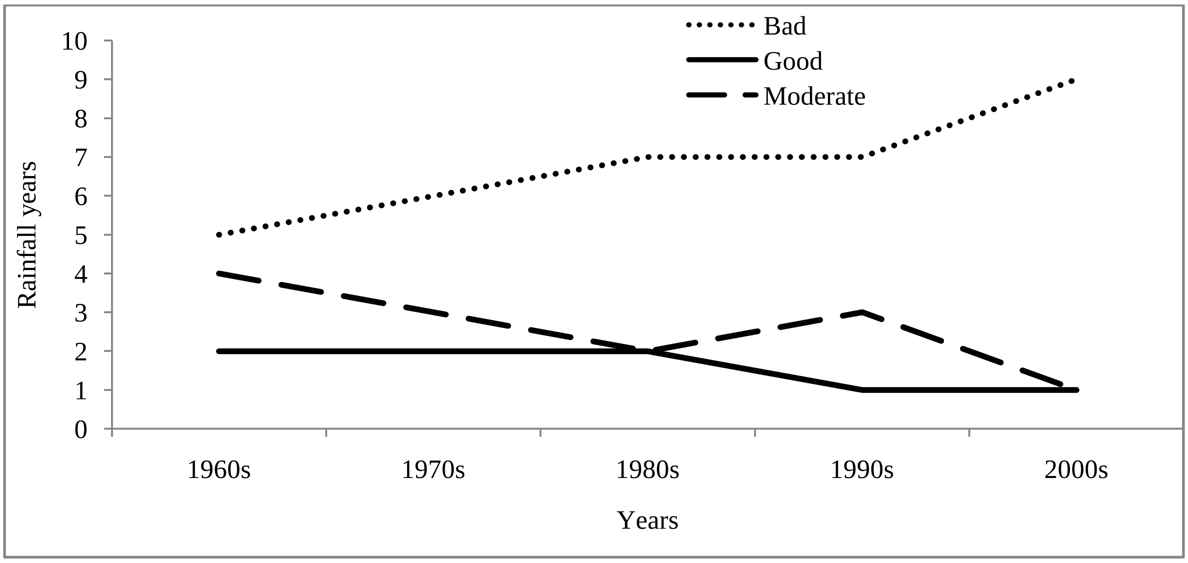
Agro-ecological zone	County	County areas	Types of crops
Semi-arid (>450 to >900 mm	Kajiado	Toroka, Mashuru, Enkutoto, Ilushon, Emashini	Maize, beans, green grams, pigeon peas fruits and vegetables
	Makueni	Makueni-, Makindu, Kiboko, Kibwezi, Mtito Andei,	Maize, beans, coffee and pigeon peas Cotton, green grams millet and sorghum
Arid (<300 to ≤450 mm)	Makueni	Masongeleni and Kambu	Maize, beans, pigeon peas, cassava, sorghum, millet
	Kajiado	Loodokilani, Elangata Wuas, Ordapoi, Oltepesi	Maize, beans and pigeon peas

Source: Adapted from Makueni and Kajiado County Development Plans (2004-2008); Gichohi (2000b).

6.5.6 Interaction between Maize Crop and Rainfall in the Study area

To understand the interaction between crops and rainfall in the study area, maize was used as an example, given that it is a staple food in both counties. In addition, it provides 42 per cent of the dietary intake in Kenya (World Resources Institute, 2007). Besides, it is the worst hit compared to other cereals when rainfall becomes unreliable and unpredictable. Makueni Composite maize requires a seasonal rainfall of at least 250 mm (Mortimore and Wellard, 1991 as quoted by Gichohi, 2000b). This was therefore used as a threshold value for defining a bad rainfall season. Seasonal rainfall was divided into three classes, (1) bad seasons with rainfall less than 250 mm; (2) fair seasons with a range of 250 to 350 mm; and (3) good seasons with rainfall greater than 350 mm. Figure 6.5 presents the distribution of rainfall years in terms of bad, fair and good in regards to maize production. Bad seasons occur characteristically in runs of 2 to 5 seasons resulting in severe food shortages. Analysis of the frequency of bad, fair and good seasons for each decade shows that 1980s had the highest percentage of good seasons, while the 2000s had the highest percentage of bad seasons (Figure 6.5). The results are compatible with those of Jaetzold and Schmidt (1982), Downing *et al*. (1988) and (Gichohi, 2000a). These scholars do recognise that weather conditions experiences vary from decade to decade; and worsen from one decade to another.

Figure: 6.5: Maize as a proxy for bad, moderate and good years for Makueni County

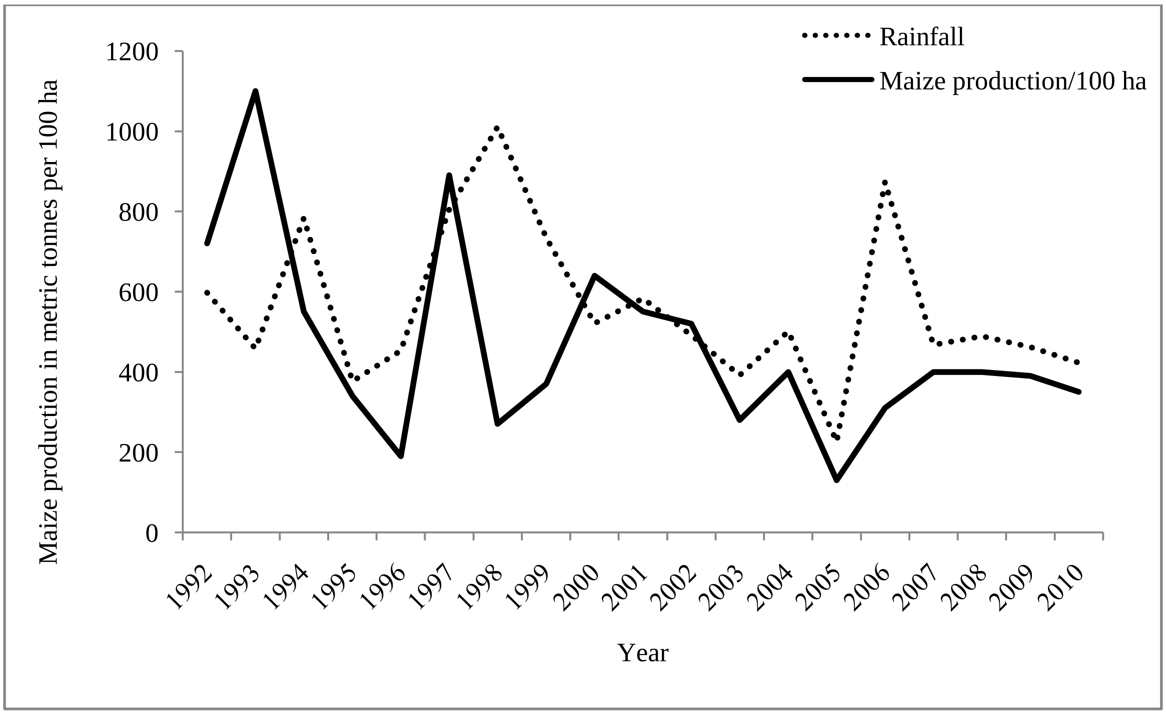


Source of Data: KIPPRA (2010); Kajiado County Livestock Office Annual Report (2008; 2009; 2010); Kajiado, DWA, KEFRI and Makindu Meteorological Stations.

Figure 6.6 shows the relationship between rainfall and total maize produced in Makueni County. Maize production peaked in early 1990s but has since stagnated due to declining yields. De Groote *et al*. (2005) established that in early and late 1990s, maize production was at its peak, but a decline in trend has been evident from 2000 to 2005. The lowest maize production was in 2005 and it coincides with the lowest mean annual rainfall received between 1992 and 2006. However, high rainfall amounts do not necessarily translate into high maize production. For example, the highest maize production of 11000/m^2 was noted in

1993 when the mean annual rainfall was 458 mm. This implies that rainfall level is not enough but rather other parameters including distribution, intensity remains critical. Again, rainfall levels were highest in 1997/1998, yet maize production still declined. Therefore, too much of rainfall have counter effect on crop production, salinity and soil PH. In support, Ketien *et al.* (2008) established that the decline in maize yields in Mtwapa and Kitale were related to rainfall variability and soil fertility. Also, Allen (1971) and Evans (1993) noted that in Kenya, maize production is influenced by rainfall, temperature, day length, solar radiation and humidity. He further emphasised that rainfall and its distribution remain fundamental in maize farming.

Figure 6.6: Relationship between rainfall and maize production in Makueni County



Source of Data: KIPPRA (2010).

6.5.7 Perception of causes of Land-use Change in the Study Area

In order to understand the land-use dynamics in the study area, households were asked to narrate how their land-use practices have evolved over time (Table 6.6). In Makueni County, about 75.8 per cent agreed that land-use had changed, 22.2 per cent stated it had not and while the remaining (2.2 per cent) had no idea. The likely explanation for the latter was that these households were relatively new to the county and had lived in the county for less than six months.

Table 6.6: Changes in land-use over time in Kajiado and Makueni Counties

County	Change in land-use activities over time in the study area			
Responses	No	Yes	No idea	Total
Kajiado	44	54	0	98
Makueni	0	96	4	100
Total	44	150	4	198

The factors that have contributed to land-use change include drought, rapid expansion of human population, poor government policies, and reduced forage for livestock and lack of water. These factors may act either singly or in combination to influence livelihoods. Households in both counties acknowledge that extreme weather event and in particular drought has significantly contributed to transformation of the various land-use practices in the study area. Besides, it is understood that drought does not act in isolation to influence land-use change, but in combination with other factors. Only 17.3 per cent felt that drought singly contributed to land-use change (Table 6.7).

From the survey, drought associated with rainfall unreliability was cited by the respondents to be a cross-cutting factor determining the decisions on how to use farm and grazing land. Other factors cited include seed availability, soil fertility, land size, demand and market price, purpose of growing the crop, susceptibility to pests and diseases and wildlife menace. Close to 34.7 per cent of the respondents stated that rainfall reliability, quality seeds and fertile soils were important followed by rainfall, land size and soil (30 per cent); and then rainfall and land size accounted for 21.3 per cent of the responses.

Table 6.7: Factors contributing to land-use change in Kajiado and Makueni Counties

Reasons for land-use change	County		Total
	Kajiado	Makueni	
Drought and increased farming	4	42	46
Drought and high population	16	5	21
Drought, land size, population, lack of water	9	3	12
Drought, land size, population, reduced forage	2	0	2
Drought and changes in land ownership	3	10	13
Drought and government policy	18	12	30
Drought	2	24	26
Total	54	9	150

Factors that were reported to influence the grazing land were rainfall reliability, breed of cattle, drought, milk production, water availability, pasture, land availability, land size, purpose for keeping the livestock and susceptibility to diseases and parasites. Approximately, 46.5 per cent of the responses remarked that water, pasture and land remains the most critical parameter, followed by land size, breed and rainfall (24.2 per cent); purpose, breed and susceptibility to diseases (13.6 per cent), while rainfall in isolation contributed the least (1 per cent).

When the households in the two counties were asked on the factors they would consider in selecting non-farm activities. Majority (70.2 per cent) mentioned location was very important especially with business related ventures and rentals; followed by those who would not put any specific consideration (23.2 per cent), while 4.1 per cent and 2.5 per cent would consider climate related issues and purpose of the land-use respectively.

6.5.8 Climate Variability and Household Herd Sizes

The number of livestock owned in terms of Livestock Tropical Units (TLU) in the two counties varied greatly. The mean herd size for Kajiado County was 33.83 TLU compared to 8.9 TLU for Makueni. In addition, it was noted that livestock numbers in areas receiving less than 450 mm of rainfall were more or less similar in both counties. In Makueni County, households owning less than 10 TLU were the majority under the two different rainfall regimes (Table 6.8). This was followed by 10-20 TLU, 20-30 TLU and lastly more than 30 TLU. The likely reason for this trend is that these areas have slightly higher potential for agriculture than areas receiving less than 450 mm of rainfall; hence there has been an influx of people leading to increased cultivation and more demand for agricultural land, thus limiting the space available for livestock grazing. For Kajiado County, households owning more than 30 TLU were the majority while those having 1-10 TLU were the least. This can be explained by the fact that even though land has been sub-divided in Kajiado County, most households still own land as a group, which still allows for vast areas for grazing. Therefore, livestock keeping is central to the livelihoods of these households.

In support, several studies have shown that livestock numbers are driven by rainfall via its direct effects on vegetation (Poshiwa *et al.*, 2011; De Leeuw *et al.*, 1984). They affirm that rainfall fluctuations have a role to play in livestock dynamics, both in numbers and distribution. According to Poshiwa *et al.* (2011), rainfall, primary production and cattle density are interlinked in southeastern lowveld of Zimbabwe. Similarly, De Leeuw *et al.* (1984) noted that estimates of livestock carrying capacity were usually derived directly from rainfall factors. He further stated that the average carrying capacity increases from about 7ha/TLU in the south of Kajiado County where annual rainfall is 300 mm to about 3ha/TLU in the north where the average rainfall is 550 mm.

Table 6.8: Relationship between rainfall and livestock numbers

County	Rainfall amounts	Livestock Numbers in TLU				
		0 to ≤10	>10 to ≤20	>20 to ≤30	>30	Total
Kajiado	Less than or equal to 450 mm	5	17	19	19	60
	More than 450 mm	1	6	25	25	38
Makueni	Less than or equal to 450 mm	15	7	2	1	25
	More than 450 mm	52	14	5	4	75

6.5.9. Climate Variability (Rainfall) and Household Size

The mean household sizes for Kajiado and Makueni were 4.76 and 4.17 adult equivalents respectively. The majority (57.4 per cent) of households in the study area had household sizes of between 3-6 adult equivalents (Table 6.9).

Table 6.9: Relationship between rainfall and household sizes in Kajiado and Makueni Counties

County	Rainfall amounts	Household sizes in adult equivalent				
		0 to ≤3	>3 to ≤6	>6 to ≤9	>9	Total
Kajiado	Less than or equal to 450 mm	10	34	16	0	60
	More than 450 mm	9	20	6	2	37
Makueni	Less than or equal to 450 mm	5	13	7		25
	More than 450 mm	22	46	7		75
Total		46	113	36	2	197

6.5.10 Climate Variability (Rainfall Amounts) and Household Food Security

Table 6.10 presents the results of the descriptive analysis associated with the rainfall amounts and household food security. The analysis is disintegrated by the rainfall and land-use type in the study area. In general, 57.1 per cent of the households in the study area were food secure while the remaining 42.9 per cent were food insecure. Considering individual counties, households in Kajiado County were more vulnerable to food insecurity with VFI of 0.59 than Makueni County that had a VFI of 0.27. Rainfall was found to influence household vulnerability to food insecurity. For instance, in Kajiado County, majority (84.5 per cent) of the food insecure households were found in areas receiving less than 450 mm of rainfall. The reverse was noted in Makueni County where a majority of the food secure (76 per cent) were found in areas with more than 450 mm of rainfall.

Even though a study by Amwata (2004) did not take into consideration climate variability or rainfall parameters, it noted that agropastoral and pastoral household vulnerability to food insecurity were 0.2 and 0.6 respectively. The current study establishes that the vulnerability of agropastoral households to food insecurity is 0.27 while that of pastoral households being 0.59. Comparing the findings of Amwata and the current study, vulnerability of agropastoralists has increased with seven per cent and that of pastoralists has decreased by one per cent.

Table 6.10: Relationship between rainfall and household food security in the study area

County	Rainfall amounts	Household food security status		
		Food insecure	Food secure	Total
Kajiado	Less than or equal to 450 mm	49	14	63
	More than 450 mm	9	26	35
Makueni	Less than or equal to 450 mm	9	16	25
	More than 450 mm	18	57	75
Total		85	113	198

6.6 CONCLUSION AND POLICY IMPLICATION

Climate variability, specifically rainfall remains a critical factor influencing land-use systems and livelihood strategies in the ASALs. Areas with semi-humid to semi-arid climate attract different types of crops including horticulture thus pressure for fragmentation of land into smaller pieces in these agro-ecological zones. As more households revert to cultivation, less land is available for grazing, leading to reduction in cattle numbers but with increase in small ruminants such as sheep and goats that are able to withstand harsh climatic conditions.

The study shows that climate factors such as rainfall influences farm-based and household factors. For example, households located in areas receiving high rainfall tend to have smaller land sizes than their counterparts in low rainfall areas. Also, households located in arid areas tend to keep more livestock than those in sub-humid to semi-arid areas due to availability of large tracks of land for grazing. As well, rainfall influences the type of crops grown in each of the county. Makueni County that is relatively wet has options for growing food crops, root crops, oil crops and horticultural crops. This was not the case with Kajiado County that had limited ability to grow horticultural crops.

In response to the changing climatic conditions like drought, both pastoral and agropastoral households have continued to devise survival strategies in isolation, without taking into consideration the interaction among these different production systems. However, these production systems have shown some similarities in adaptation options such as migration and diversification. Therefore developments in the ASALs need to holistically adopt a systems approach to land management taking into consideration all existing land-use systems in the study area as a pre-requisite for sustainability of ASAL ecosystems.

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CHAPTER SEVEN

FACTORS INFLUENCING HOUSEHOLD VULNERABILITY TO FOOD INSECURITY IN THE SOUTHERN RANGELANDS OF KENYA: APPLICATION OF SIMULTANEOUS EQUATION MODEL WITH CROSS-SECTIONAL DATA

7.1 SUMMARY

Household food security remains one of the greatest challenges for governments in Africa, despite their efforts in ensuring national food security. However, a dearth of information exists on the factors influencing households' vulnerability to food insecurity. This study was conducted to establish the determinants of household vulnerability to food insecurity in two ASAL counties of Kenya. A sample of 98 households was randomly selected from Kajiado County and 100 households from Makueni County. The locations sampled in Kajiado County include Loodikilani, Nkoile, Enkaroni, Enkorika, Olobelbel, Osilalei, Oloontulugum and Mashuru while for Makueni County are Kiboko, Nguumo, Masongeleni, Kambu, Mtito Andei, Makindu and Kikumbulyu.

Data were collected through questionnaire interviews, direct observations and literature review of previous reports and peer-reviewed publications. Using descriptive analysis to assess household food security status, the results showed that households in Kajiado County, which is predominantly a pastoral community, were more vulnerable to food insecurity (VFI) with a VFI of 0.59 than households in Makueni County which had a VFI of 0.27. A two stage least squares (2SLS) approach was used to establish the factors influencing the vulnerability of households to food insecurity. These factors varied between the two counties. For Makueni County, the determinants of household vulnerability to food insecurity were land size, household size, rainfall and herd size. On the other hand, the determinants in Kajiado County were access to climate information, herd size, off-farm employment and gender of the household head. Therefore, development interventions for Makueni County need to ensure; access to and control over land resources, dependency is kept at its minimal, destocking through improved livestock breeds and creation of a micro-climate to help attract more rainfall. Similarly for Kajiado County, policies should focus on enhancing access to climate information, destocking through improved livestock breeds, diversification of livelihoods and promoting access of production resources to female headed households.

7.2 INTRODUCTION

Kenya's long term goal of self food sufficiency remains unmet. Frequent droughts precipitate requests for donor-provided food aid to mitigate the ravages of famine, especially in ASALs, populated largely by livestock dependent pastoral tribes (USDA, 2009). Kenya, just like other African countries, is faced with hunger and poverty and these problems are getting worse. It is estimated that more than 14.3 million people or 60 per cent of the population live below the poverty line (ROK, 2009). In addition, about 52.9 per cent of the population living in the rural areas and 34.8 per cent of those living in urban areas are poor. Besides, 49 per cent of the rural population is absolutely poor (Kenya National Bureau of Statistics, 2007) and 7.6 per cent of the urban live in extreme poverty, such that they cannot meet their food needs even if their entire resources were devoted to food.

Kenya has a population of more than 38 million about ten per cent of whom are classified as food insecure. With an annual growth rate of about three per cent, the country remains the largest import market for food and agricultural products in East Africa. In an attempt to mitigate the food crisis during 2009, Kenya imported about $725 million in agricultural products, a figure much higher than the $525 million in 2007 (ROK, 2009). The Government of Kenya has identified droughts and erratic rainfall as the main reason for vulnerability to food insecurity in the ASALs (within which the study area falls). Furthermore, agricultural development is considered the main source of food security but it is also recognised that agriculture alone cannot ensure food security to the masses in the long run (ROK, 2010).

The factors contributing to food insecurity and related survival mechanisms vary with people and region. The causes and possible remedies of hunger in Kenya are still unclear. There is therefore need for research and empirical analysis to provide scientific facts for public policy formulation and action for minimising food insecurity and adapting to impacts of climate variability and change. More evidence on this issue is necessary, particularly at the household level. The current study attempts to fill this gap by providing further guidance on the problem of climate variability and its links to household vulnerability to food insecurity in the ASALs of Makueni and Kajiado Counties.

7.2.1 Definitions and Concepts about Food Security

Food security has been defined by many authors depending on the context and purpose of the study. According to FAO (2002) and Tasokwa (2011) food security refers to when all the people at all times have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active healthy life. Thus it describes a condition when people have adequate access to food and nutrition. Amwata (2004) defines food security as the availability of adequate diet all year round, that is, 2250 kcal/AAME/day. Other studies such as those of Nyariki and Wiggins (1999) states that food security is attained when sufficient growth in food crops and livestock is achieved not only to maintain output per person, but also to reduce food calorie deficits and to lower food imports. Nyariki and Wiggins (1997) defines food security as access by all people at all times to enough food for an active healthy life. At the macro level, food security implies that adequate supplies of food are available through domestic production or through imports to meet the consumption needs of all people in a country. At the micro level (household or individual), food security depends on a number of factors which are related to various forms of entitlements such as income and food purchasing power. Therefore, food security is a function of income and purchasing power, hence its strong relationship with poverty.

The current study adopts the definition by Ganapathy *et al.* (2005) and Power *et al.* (1998) that see the core of food security as a bivariate concept composed of anti-hunger or poverty elimination goals on the one hand and goals related to food system issues on the other. The two dimensions of the concept essentially relate to food access goals in terms of quantity and quality, respectively. An anti-hunger or anti-poverty approach argues that people should have a sufficient quantity of food and/or enough income to access a sufficient quantity. The food system approach expresses a concern with the quality of food that is available, how food is produced and the impact of its production, distribution and consumption on individuals and communities.

7.2.2 Methodologies used in Household Food Security Studies

Different methodologies have been used by various scholars to establish the factors influencing household vulnerability to food insecurity using qualitative and quantitative approaches. Some of the studies that have used quantitative approaches are Amwata (2004), Kaluski *et al.* (2009), Nyariki *et al.* (2002), Pankomera *et al*. (2009), Amaza *et al.* (2009), and Tasokwa (2011). On the other hand, qualitative studies have been conducted by Wolfe and Frongillo (2001), Oni *et al.* (2010) and Bartfeld and Hong-min (2011). In both qualitative and quantitative studies, the logit, probit and multiple regression models have been widely used in establishing the determinants of household food security. The most commonly reported determinants of household food security in these studies include the education level of the household head, land size owned by a household, household size, household income, access to credit facilities, access to markets and gender, among others.

For instance, Amwata (2004) used a binary logit regression model to estimate the determinants of household food security. She found out that gender and land ownership were the main determinants of household food security in Kajiado District. Nyariki *et al*. (2002) used Ordinary Least Squares (OLS), Weighted Least Squares (WLS) and Feasible Generalized Least Squares (FGLS) models in determining the factors influencing household food security in Makueni County. He found out that WLS produced better results in terms of R^2 and number of significant variables with income being the main determinant of household food security. Other studies from Africa, such as Pankomera *et al.* (2009), used a binary probit regression model, and reported household size and education level of the household head as being among the main determinants of household food security.

In the above mentioned studies, the food security measure was either binary or continuous. The underlying assumption in the above models was that there is a one-way relationship between food security and its determinants. This assumption is disputed by Tasokwa (2011) who argued that these factors can be categorised into two, namely agricultural and social factors, which are often intertwined in terms of their influence. This implies that they include exogenous, endogenous and instrumental variables that result in a two-way relationship between food security and its explanatory variables. Therefore, similar to Tasokwa (2011), this current study uses a simultaneous equation model (SEM) to estimate the factors influencing household vulnerability to food insecurity.

7.3 METHODOLOGY

7.3.1 Area of Study and Data Collection

This study was conducted in Makueni and Kajiado Counties of Kenya. The two counties are located in the southern rangelands of Kenya. Makueni County covers an area of 7,965.8 km^2 and had a human population of 884,527 in 2009 (CBS, 2009) with an annual growth rate of 2.8 per cent. Kajiado County covers approximately 19,600 km^2 and lies between longitudes 36º 5’ and 37º 5’ east and 1º 0’ and 3º 0’ south (CBS, 1981). Both counties are classified by the Kenyan Government as arid and semi-arid, characterised by variable and unpredictable rainfall patterns, dry spells and droughts. The rainfall regime in the two counties is bimodal with long rain falling between March and May and short rains in October to December. Therefore there are two growing seasons. The main food crops for both counties include maize, beans, and pigeon peas while cereals such as millet, sorghum are also grown. The population in these counties are primarily small-holder subsistence farmers and/or livestock keepers who wholly depend on rainfall for their livelihood.

A multistage sampling technique was used to select 198 households, 98 from Kajiado County and 100 from Makueni County. First, these two counties were purposely sampled based on the main land-use activities, culture, weather conditions and livelihood sources. The locations in each county were listed and eight randomly selected for each county for the study. Then, 100 households were randomly selected for the administration of questionnaires. Household interviews were conducted from March to September 2009. The data collected were on land-use, livelihood sources, household size, gender of the household head, household total income, land size, herd size, types of crops grown and their acreage, rainfall, rain days, temperature patterns, and access to climate information.

7.3.2 Measuring Household Food Security

Various scholars have used different methods to measure household food security. Some studies have used child nutrition as a measure of household food security, especially when the security of intra-household nutrition is a concern (Kigutha, 1994). In this approach, attention is given to women and children, the most vulnerable members of the poor households. It is estimated that 2.3 million children aged 6-24 months die annually in developing countries due to malnutrition (Tangka *et al.*, 2000). Such households discriminate among its members in distributing food when food supply is inadequate but declines with plenty supply. Also parameters such as Weight-for-Age (W/A), Height-for-Age (H/A), Weight-for-Height (W/H), head circumference, and mid-arm circumferences for different age groups have been used as a basis for assessing malnutrition and evaluating the effects of dietary treatment in children. Weight, height, head circumference and mid-arm circumference for age are the percentages of adequacy of each of these measurements based on the respective standards for the children's chronological age (Kigutha, 1994; Tangka *et al.*, 2000).

Vulnerability to food insecurity (VFI) has also been used to determine household food security or food poverty status (Amwata, 2004; Sunya, 2003; ROK, 2000a; Nyariki and Wiggins, 1997). One of the indexes used to estimate food poverty is the food poverty incidence (FPI). FPI is the ratio of food poor households to all households in a community. The ratio gives the food vulnerability status of the community under investigation (Amwata, 2004; Nyariki *et al.*, 2002). The studies mentioned above have emphasised on actual household food consumption as a measure of vulnerability to food insecurity. This current study uses food consumption but from income approach. The argument is that one can only access enough food if he or she can produce it or if they have adequate income to purchase the food. According to the Government of Kenya (ROK, 2000a) poverty lines for Kenyans in rural and urban areas are Kshs 1,239/month/adult equivalent and Kshs 2,648/month/per adult equivalent respectively. Kenyans living below these standards are thus considered to generate inadequate income levels to feed, clothe, educate and pay for basic health care for their families. A similar approach has been used by Kristjanson *et al.* (2002) in valuing alternative land-use options in the Kitengela dispersal area of Kenya.

The current study uses income per adult equivalent approach to estimate household vulnerability to food insecurity. This approach involves collection of data on household total income and the number of individuals present. Total income refers to an aggregate value of livestock, crop and off-farm income in a given time period (Kristjanson *et al.,* 2002). In addition, the number of members present in a household was standardized into adult equivalents (AE). The concept of AE is based on the differences in nutritional requirements according to age and sometimes sex. It assumes the lifecycle stages have an important influence on the needs of members or individuals of the same household (Kristjanson *et al.,* 2002). Various consumption weights have been proposed over time. This study has adopted the consumption weights by age where: 0-4 years is 0.24 AAME; 5-14 years, 0.65 and over 15 years, 1.00 (ROK, 2000b). Depending on the size and ages of the household members, adult equivalent (AAME) is derived.

Total income per household per month divided by the sum of Active African Man Equivalence (AAME) gives the income per adult equivalent per month. In the descriptive analysis of food security, the figure obtained was compared to the recommended income per adult equivalent per month for the rural area of Kshs 1,239 (See, for example, Kristjanson *et al.,* 2002).

For the calculation of household vulnerability to food insecurity, the equation below was used:

$VFI_t = Ya/Yr$

Vulnerability to food insecurity (VFI_t) at time t = Actual total income per adult equivalent/month for a household (Ya) divided by the required total income per adult equivalent/month for that household (Yr).

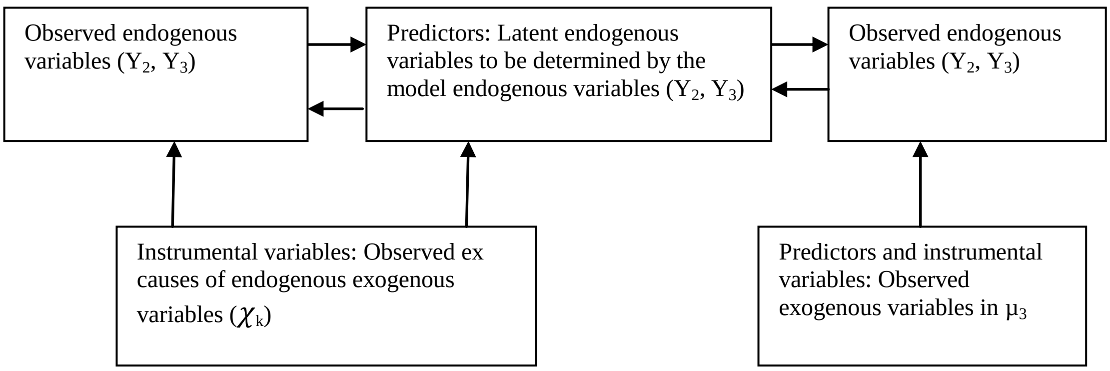
The households' vulnerability to food insecurity is the proportion of households who fall below the poverty line of Kshs 1,239 per adult equivalent per month. The food poor households are those who do not have access to income of Kshs 1,239 per adult equivalent per month. Households whose members have access to income of Kshs 1,239 and/or above per adult equivalent are considered less vulnerable to food insecurity.

7.3.3 Determinants of Household Vulnerability to Food Insecurity

A simultaneous equation model (SEM) was used to assess the determinants of household food security. The dependent variable was the household food security measure, using total income per adult equivalent per month as an indicator. The independent variables hypothesised to influence household food security included farm and household-level factors. Some of the explanatory variables are agriculture related, most of which are expected to have a two-way feedback. Therefore, the problem of simultaneity was expected in the model, hence the choice of a simultaneous equation model. The simultaneity problem was confirmed by Hausman specification test. The assumption was that there were exogenous and endogenous variables in the model which could not be estimated through OLS approach. Instead, a 2SLS approach was used to estimate the model.

The model was conceptualised that household food security is a relationship between the amount of income per adult equivalent per month and the household characteristics, farm characteristics, on-farm employment, and rainfall levels. Even though similar studies, such as Tasokwa (2011), have assumed that climatic parameters such rainfall and temperature intensity could not be included in the model due to the assumption that climate is a community factor, this study found otherwise; that households within the community experience different levels of rainfall due to differences in agro-ecological zones and altitude. Land size, herd size and household size were presumed endogenous because they are influenced by other factors such as income, rainfall and household size which are also explanatory variables. Therefore they are likely to correlate with the error term. Hausman test for exogeneity, as suggested by Gujarati and Sangeetha (2007), was conducted to confirm the endogeinity of the variables. The assumption in the model was that income per adult equivalent is influenced by three main endogenous variables, land size, herd size and household size, and other exogenous variables. However, education and land size also influence each other and are in turn influenced by the availability of income and some exogenous variables which are not included in the main equation. The model, therefore, contains the dependent variable, predictors, predictors and instrumental variables, and purely instrumental variables (Figure 7.1). Instrumental variables are exogenous variables that influence the endogenous variables in the model but are not included in the main equation of the model.

Figure 7.1: Theoretical framework for SEM



Predictors and instrumental variables are exogenous variables that are included in the main equation of the model. Household characteristics include household size, gender, education and age of the household head. Farm characteristics include farm size, labour, access to climate information and sources of climate information. Earnings include household income from farm and off-farm employment. Thus, vulnerability of households to food insecurity depends on the factors, which influence production and purchase of food. These factors are interrelated in nature as shown in Figure 7.1.

The model can be expressed as:

$$Y_1 = \beta_{10} + \beta_{11}Y_2 + \beta_{12}Y_3 + \beta_{13}Y_4 + \lambda_1 \chi_{m1} + \lambda_2\chi_{m2} + \lambda_3\chi_{m3} + \cdots + \lambda_n\chi_{mn} + \mu_1 \quad (7.1)$$

$$Y_2 = \beta_{20} + \beta_{21}Y_2 + \beta_{22}Y_3 + \beta_{23}Y_4 + \varphi_1 \chi_{k1} + \varphi_2\chi_{k2} + \varphi_3\chi_{k3} + \cdots + \varphi_n\chi_{kn} + \mu_2 \quad (7.2)$$

$$Y_3 = \beta_{30} + \beta_{31}Y_2 + \beta_{32}Y_3 + \omega_1 \chi_{p1} + \omega_2\chi_{p2} + \omega_3\chi_{p3} + \cdots + \omega_n\chi_{pn} + \mu_3 \quad (7.3)$$

$$Y_4 = \beta_{40} + \beta_{41}Y_1 + \alpha_1 \chi_{l1} + \alpha_2\chi_{l2} + \alpha_3\chi_{l3} + \cdots +_n \chi_{ln}\mu_4 \quad (7.4)$$

Where Y_1 is a dependent variable, Y_2, Y_3 and Y_4 are endogenous variables or jointly dependent variable, $\chi_{k's,m's,}$ $\chi_{p's}$ and $\chi_{i's}$ are observed exogenous variables or predetermined variables associated with given equations, β_{10}, β_{20}, β_{30}, and β_{40} are constants, β's are coefficients for endogenous variables (Y), λ's, ω's, φ's and α's are coefficients for exogenous variables (χ), and μ_1, μ_2, μ_3 and μ_4, are stochastic disturbances.

7.3.4 Test for Identification, Simultaneity and Exogeneity

Tests for identification, simultaneity and exogeneity were formally carried out. The order and rank condition of identification as described by Gujarati and Sangeetha (2007) and Tasokwa (2011) were used to find out if the equations were exactly identified or overidentified. The order condition demands that the number of exogenous variables excluded from an equation must not be less than the number of endogenous variables in that equation less 1. That is to say, if K-k = m-1, the equation is exactly identified but if K-k>m-1, it is overidentified.

K is the number of exogenous variables in the model including the intercept, k is the number of exogenous variables in the given equation and m is the number of endogenous variables in a given equation. Therefore, the order condition is a necessary but not sufficient condition for identification. Hence, a rank condition of identification was used because it is both a necessary and sufficient condition of identification. It states that, "in a model containing M equations, an equation is identified if and only if at least one nonzero determinant of order (M-1) (M-1) can be constructed from the coefficients of the variables (both endogenous and exogenous) excluded from that particular equation but included in the other equations of the model" (Gujarati and Sangeetha, 2007; Tasokwa, 2011). The advantage of using both conditions is that the rank condition tells whether the equation is identified or not while order condition tells whether the equation is exactly identified or overidentified. The 2SLS approach provides satisfactory estimates of parameters and is suitable for estimation of overidentified equations (Vogel and Adams, 1999; Tasokwa, 2011).

The methods of 2SLS and instrumental variables (IV) give consistent and efficient estimates if there is simultaneity in the model. Therefore, the test of simultaneity was essential to find out if a regressor was correlated with the error term. Hausman specification error test was used for this purpose. The steps were undertaken as follows:

1. Regress each endogenous variable (Y_2, Y_3 and Y_4) on all the exogenous variables (X_k, Z_k) (reduced form equations) to obtain estimated μ_2, μ_3 and μ_4.
2. Regress the dependent variable (Y_1) on all endogenous variables and the estimated residuals and perform a t-test on the coefficient of the estimated residuals. If the coefficient is statistically zero, then there is no simultaneity in the model.

Further, it was not obvious to determine the variables which were endogenous in the model. Hausman test was used to test if the endogenous variables were truly endogenous. The test was carried out as follows:

1. Regress each of the endogenous variables on all the exogenous variables in the model to obtain estimated endogenous variables (Y_2*, Y_3* and Y_4*).
2. Regress the dependent variable on the endogenous variables (Y_2, Y_3 and Y_4), fitted endogenous variables (Y_2*, Y_3* and Y_4*) and exogenous variables (X_k) and use the F-test to test the hypothesis that the coefficients of the estimated endogenous variables are equal to zero. If the hypothesis is rejected, the endogenous variables are truly endogenous.

7.4 RESULTS AND DISCUSSION

7.4.1 Results of Descriptive Analysis

Table 7.1 presents the results of descriptive analysis associated with the dependent and explanatory variables used in the model. The analysis is on the basis of land-use systems. Using a computed food security measure, the results showed that Kajiado households were more vulnerable to food insecurity (0.59) than Makueni households (0.27). However, as expected, rainfall levels were found to influence household vulnerability to food insecurity. For instance, in Kajiado County, the majority (84.5 per cent) of households who were food insecure were found in areas receiving less than 450 mm of rainfall. Conversely, for Makueni County, the majority (76 per cent) of the food secure were found in areas receiving more than 450 mm of rainfall. The study was carried out in a 'normal' year when the environmental factors were considered average. However, the vulnerability to food insecurity is expected to be higher than this finding in a year of drought because household food consumption behaviour changes during a dry season.

The mean total income was also found to vary with rainfall levels. The mean household income per adult equivalent/month was Kshs1,138.5 and Kshs 1,386.0 for Kajiado and Makueni Counties respectively. Those living in areas with less than 450 mm of rainfall had the lowest total income per adult equivalent in both Kajiado and Makueni Counties. In Kajiado County, those who received less than 450 mm of rainfall had a mean income/adult equivalent/month of Kshs 808 and those in more than 450 mm of rainfall had income per adult equivalent per month of Kshs 1,345. Similarly for Makueni County, those living in areas of less than 450 mm of rainfall and those in more than 450 mm of rainfall had income/adult equivalent/month of Kshs 1,198 and Kshs 1,422 respectively.

The results showed that household heads from Kajiado County had low levels of education with about 63.3 per cent having no formal education as compared to 3 per cent in Makueni County. In Kajiado County, approximately 62.9 per cent who had no formal education were found in areas receiving less than 450 mm of rainfall. However, the situation was different in Makueni County, where all those who had no formal education were found in areas receiving more than 450 mm of rainfall and they were found to be immigrants who had been employed to take care of the farms for the absentee landlords who were either in Nairobi or Mombasa.

This result concurs with that of Amwata (2004), who noted that agropastoral households in Kajiado District had more formal years of schooling than their transhumant counterparts. The likely explanation is that pastoral households tend to concentrate more in the remote areas that have limited social facilities including schools and hospitals. Hence schools are few and long distances have influenced the households' school enrolment.

In terms of age, young household heads aged 18-30 years were not found in areas receiving less than 450 mm of rainfall for both Kajiado and Makueni Counties. However, for Kajiado County, about 60.4 per cent of those aged more than 50 years were found in areas receiving less than 450 mm of rainfall. In contrast, about 72.5 per cent those aged more than 50 years were found in areas receiving more than 450 mm of rainfall in Makueni County. The likely explanation is that most of the young, aged 18-30, are educated and dynamic and hence maximise opportunities by diversifying to other income generating activities. Similarly, the old household heads in Makueni County, have accumulated many years of wisdom in farming and have developed coping strategies, which have made them survive in these areas, despite rainfall variability. In contrast, the old household heads in Kajiado County still have cultural ties to their livestock, thus they prefer to stay in remote and dry areas where there are large tracts of land for grazing.

Access to climate information is critical for climate variability and change adaptation. The finding of this study shows that more households (86 per cent) in Makueni County compared to Kajiado County (42.9 per cent) had access to climate information. Nevertheless, about 67.9 per cent of the households who had no access to climate information were found in areas of less than 450 mm of rainfall. The reverse was noted in Makueni where 77.9 per cent of those who had access to climate information were found in areas with more than 450 mm of rainfall. Conversely, a great disparity was noted in the source of climate information for the households in Kajiado and Makueni Counties. In Kajiado County, 82.7 per cent relied on traditional sources while in Makueni County 92 per cent relied on conventional sources of climate information. The traditional sources of climate information included observations by local weather men, signs associated to animals, birds and physiological development of plants. The conventional sources included meteorological stations, radio, television and audio visuals. The most common reason cited by those who did not access climate information was unavailability of a radio in their household or in the neighbourhood coupled with their households' locations.

Table 7.1: Summary of the sample characteristics based on rainfall and land-use

Variables	Unit, definition	Kajiado (Pastoralists)		Makueni (Agropastoralists)	
		Less than or equal to 450 mm	More than 450 mm	Less than or equal to 450 mm	More than 450 mm
		Mean	**Mean**	**Mean**	**Mean**
Dependent Variable					
Total income per adult equivalent/month	Kenya shillings per month	808	1,345	1,198	1,422
Explanatory Variables					
Household characteristics					
Gender of the household head	Binary, 1 for male and 2 for female	1.05	1.23	1.56	1.48
Education levels of household head	Scaled 0-3, 0 for no education, 1 for primary, 2 secondary and 3 for tertiary	0.76	0.75	1.68	1.69
Household size	Number of individuals present	4.84	4.66	4.6052	4.0300
Age of the household head	Age in years	49.98	46.18	44.10	42.39
Experience of the household head in the area	Experience in years	46.71	43.43	27.44	31.01
Income per adult equivalent/month	Kenya shillings per year	808	1,345.0	1,198.0	1,422
On-farm income	Kenya shillings per year	75879.31	59552.50	32402.40	35191.790
Off-farm income	Kenya shillings per year	26839.48	22461.88	41770.00	22696.922
Expenditure on food items	Kenya shillings per year	64780.41	52395.15	55597.96	20620.497
Expenditure on non-food items	Kenya shillings per year	16188.22	11748.10	14416.04	6450.963
Herd size	Tropical livestock unit	26.42	46.09	0.8100	0.7389
Farm characteristics					
Land size	Acres	187.84	228.03	24.20	15.44
Access to climate information	Access binary: 1 for yes and 0 for No	0.00	0.00	0.76	.89
Source of climate information	Category, 1-3	1.14	1.18	1.96	2.01

The climate indicators used in the study area were trees, animals, insects and birds. Trees were the most popular climate indicators. The importance of traditional methods of predicting climate has been in existence as long as human kind. For instance, in the bible, the fig tree was used as a seasonal indicator (Tasokwa, 2011). Similarly, studies by Ogallo (2004) have underscored the role of traditional climate indictors in modern science.

The households in Kajiado and Makueni Counties monitor the wind, position of the sun and the associated shadows, plants, insects (bees in particular) and animals to predict the seasonal rainfall performance and onset. The major rain season of interest is October to December, which is the most reliable in the area and is monitored in anticipation of much food production. The results indicate that the traditional methods are still widely used among the communities; though they also have some relationships with modern scientific methods. The indicators help the community to mitigate disasters by using traditional methods to predict weather and plan land-use activities. Examples of land-use activities include growing drought tolerant crops such as cowpeas, pigeon peas, *lab lab* and green grams. In livestock, the activities include keeping drought tolerant animals, planning of grazing management, splitting of herds and diversification. The communities were interested in working with the modern climate scientists and requested for involvement in weather prediction and interpretation to help them make informed land-use decisions.

The indicators may be categorised into two: living and non-living things. The living things include plants in different phenological stages of development (Table 7.2); and animal indicators include bees, birds, frogs and livestock. The non-living indicators include weather related ones such as sunset clouds, lightning, heat and or temperature, wind and dust devils and astronomical factors such as hill shadows and star clusters; and hydrological factors particularly the streams/rivers. Of all these indicators, plants were the most commonly used due to their predictability and accuracy.

Table 7.2: Vegetation related indicators explored during group discussions

Botanical name	Plant or tree phenological stages and rainfall prediction
Adansonia digitata	Trees in full bloom
	Short rains are 14-21 days away
Acacia mellifera	Flowering and blooming; the flowers shed by rain. Short or long rains will fall in 15 days
Nagal atumia	Appearance of fruits. Short rains will fall in less than 15 weeks
Asparagus africana	Burst of flowers followed by fruits. Short rains will fall in the less than 5days1
Commiphora	Full bloom. Short or long rains will fall in 1 to 2 weeks time
Ficus sycomorus	Full bloom. Short or long rains will fall in 1 to 2 weeks time
Acacia tortilis	Blooming with flowers
	Blooming without flowers
	Long rains 1 week away
	Short rains will fall in the coming 2 weeks
Melia volkensii	Blooms, flowers and small fruits appear
	Short rains in the next 1 week
Boophone disticha	Pink flowers drop
	Short rains will fall in less than 2 weeks
Combretum apic	Blooms, flowers and small fruits appear
	Shot rains will fall in 1 to 2 weeks time
Combretum binderianum	Blooms and flower buds appear. Flowers drop by rain
	Short rains will fall in 1 to 2 weeks time
Dalbergia melanoxylon	Flower buds appear, blooming starts and flowers drop with rains
	Short rains will fall in 1 to 2 weeks time
Ficus Thonningii	Full bloom
	Short rains will fall in 1 to 2 weeks time
Fiscus vasta	Full bloom
	Short rains will fall in 1 to 2 weeks time
Ficus ingens	After full bloom, the colour changes from pink to light brown
	Short rains will fall in 1 to 3 days time

Source: Adapted from Ogallo (2004).

7.4.2 Simultaneous Equation Model Analysis

7.4.2.1 Test for Identification

Table 7.3 presents the results of the analysis of order condition of identifiability of the SEM. The results show that all the equations were overidentified. Therefore, it was appropriate to use 2SLS to estimate parameters in the model. However, as pointed out earlier, the order condition is not a sufficient condition for identification. Table 7.4 presents the coefficients of the variables used in the model.

Table 7.3: Order condition of identifiability

Equation	No. of exogenous variables excluded (K-k)	No. of endogenous variables included less 1(m-1)	Decision on identification
7.5	2	2	Exactly identified
7.6	2	1	Overidentified
7.7	3	2	Overidentified
7.8	5	1	Overidentified
7.9	2	2	Exactly identified
7.10	2	1	Overidentified
7.11	2	1	Overidentified
7.12	5	1	Overidentified

The equations used in the model are:

$$FS_{kj} = \alpha_0 + \alpha_{11}Sh + \alpha_{12}Ls + \alpha_{13}Hs + \lambda_1 Ge + \lambda_2 Rl + \lambda_3 Ci + \lambda_4 Ag + \mu_1 \quad (7.5)$$

$$Ls_{kj} = \alpha_1 + \alpha_{21}FS + \alpha_{22}Hs + \lambda_{11}Ge + \lambda_{12}Rl + \lambda_{13}Ed + \lambda_{14}Ag + \mu_2 \quad (7.6)$$

$$Sh_{kj} = \alpha_2 + \alpha_{31}FS + \alpha_{32}Ls + \lambda_{21}Ge + \lambda_{22}Rl + \lambda_{23}Ed + \mu_3 \quad (7.7)$$

$$Hs_{kj} = \alpha_3 + \alpha_{41}FS + \alpha_{12}Ls + \alpha_{13}Ed + \mu_4 \quad (7.8)$$

$$FS_{mk} = \beta_0 + \beta_{11}Sh + \beta_{12}Ls + \beta_{13}Hs + \varphi_1 Ge + \varphi_2 Rl + \varphi_3 Ed + \varphi_4 Ci + \mu_1 \quad (7.9)$$

$$Ls_{mk} = \beta_1 + \beta_{21}Fs + \beta_{22}Hs + \varphi_{11}Ge + \varphi_{12}Rl + \varphi_{13}Ed + \varphi_{14}Ag + \mu_2 \quad (7.10)$$

$$Sh_{mk} = \beta_2 + \beta_{31}Fs + \beta_{32}Ls + \varphi_{21}Ge + \varphi_{22}Rl + \varphi_{23}Ed + \varphi_{24}Ex + \mu_3 \quad (7.11)$$

$$Hs_{mk} = \beta_3 + \beta_4 Fs + \varphi_{41}Ls + \varphi_{42}Ed + \mu_4 \quad (7.12)$$

Where FS_{kj} and FS_{mk} stand for vulnerability to food insecurity in Kajiado and Makueni Counties respectively. Sh is the size of the herd, Ls is land size, Ed is education of head of the household, Ci is access to climate information, Cs is source of climate information, Hs is household size, Ge is gender of head of household, and Ex is years of experience in an area and Rl is rainfall levels. α_0, α_1, α_2, β_0, β_1, β_2 and β_3 are constants, αs and βs are coefficients of endogenous variables, λ's and φ's are coefficients of predictors and instrumental variables, ∞ and φ are coefficients of instrumental variables and μs are error terms.

It is not obvious to determine the variables, which were endogenous in the model. Therefore a Hausman test was conducted to test if the endogenous variables were truely endogenous. The test was carried out in two steps:

Step 1: Regress each of the endogenous variables on all the exogenous variables in the model to obtain estimated endogenous variables (size of the herd (Sh) land size (Ls) and household size (Hs) as shown in Table 7.4.[2] The results in Table 7.4 show that at 5 per cent level of significance, the coefficient of residuals for land size (0.256) and coefficient of residuals of household size (-0.407) are statistically significant, indicating presence of simultaneity problem. This implies that the hypothesis that they are equal to zero is rejected therefore, the coefficients for these residuals are not statistically equal to zero: hence, there is simultaneity problem in the model.

Step 2: Regress the dependent variables on all the endogenous variables (Y_2, Y_3 and Y_4), fitted endogenous variables (Y_2*, Y_3* and Y_4*) and exogenous variables (X_k) and conduct F-test to test the hypothesis that the coefficients of the estimated endogenous variables are equal to zero. If the hypothesis is rejected, the endogenous variables are truly endogenous.

Table 7.4: Coefficients of the variables in the SEM model for Makueni County (test for endogeneity)

Variables	Coefficient	t value
Constant		2.854**
Rainfall levels within the households	0.208	2.632**
Household access to climate information	-0.122	-1.542
Source of climate information	-0.095	-1.239
Residuals for Herd size (Sh)	-0.076	-0.991
Residuals for Land size(Ls)	0.256	3.259**
Residuals for household size (Hs)	-0.407	-5.254**
crop sales per household	0.413	5.205**
Age of the household head	-0.026	-0.336

****Significant at $p \leq 0.05$**
Adjusted $R^2 = 0.443$, F = 10.832 ($p \leq 0.05$)

[2] The regression coefficients were standardised and, therefore, the constant value is absent from the regression results presented.

7.4.2.2 SEM Results for Makueni County

Tables 7.5 and 7.6 present the coefficients and correlation coefficients of the variables used and 2SLS results for Makueni County. The results are based on the objective addressing the determining factors of household vulnerability to food insecurity.

Table 7.5: SEM Regression Results for Coefficients for variables used in Makueni County

Variables	Coefficient	t-value
Constant		-2.512**
Fitted land size (Ls)	0.339	2.605**
Fitted household size (Sh)	0.426	3.235**
Gender of the household head	-0.078	-0.625
Rainfall levels	0.320	2.487**
TLU per adult equivalent	-0.241	-1.809*
Education of the household head	-0.049	-0.361
Age of the household head	0.204	1.630
Access to climate information	-0.084	-0.691
Experience in the area	0.183	1.363

****Significant at $p \leq 0.05$, *Significant at $p \leq 0.10$**
Adjusted $R^2 = 0.336$, $F = 3.702$ ($p \leq 0.05$)

Household size had a positive and significant influence in Makueni ($p \leq 0.05$). This result indicates that large households are likely to be food secure in an agropastoral system such as Makueni County mainly because of their large labour force. This finding is consistent with findings from other studies (Reardon and Vosti, 1995), which show that large households lower the risks of poverty due to the availability of labour. In support, Amwata (2004) noted that an increase in household size leads to increased food security for both agropastoral and transhumant households. Further, Kigutha *et al*. (1994) and Kavishe and Mushi (1993) noted that large households with low dependency ratio favour resource contribution to the household because there is more food available for household consumption. However, other studies have reported the reverse, that smaller household sizes lead to higher household food security because the households have less people to feed (Tasokwa, 2011; Nyariki *et al.,* 2002). The current findings imply that larger households are less vulnerable to food insecurity.

Table 7.6: Correlation Matrix for Variables used in Makueni County SEM Model

Variables	Experience in the area	Rainfall levels	Access climate information	Gender of household head	Age of household head	Fitted Land size	Fitted Herd size	TLU/AE	Education
Experience in years	1.000								
Rainfall levels	-0.020	1.000							
Access to climate information	0.033	-0.077	1.000						
Gender of household head	-0.155	-0.004	0.005	1.000					
Age of household head	0.153	0.111	-0.151	-0.105	1.000				
Fitted land size	0.017	0.228	-0.019	0.064	-0.105	1.000			
Fitted herd size	-0.041	-0.238	0.022	-0.013	-0.188	0.235	1.000		
TLU/AE	-0.296	0.087	-0.200	0.027	0.164	-0.186	-0.099	1.000	
Education of household head	0.293	-0.098	-0.063	-0.314	0.058	0.006	0.199	0.058	1.000

*** Correlation analysis was conducted to help choose among the variables that were highly correlated. This table shows that variables included in the model were uncorrelated**

Land size had a positive and significant ($p \leq 0.05$) influence on household food security in Makueni County. The positive influence implies that households with larger land holdings are likely to be more food secure. This result supports the idea that the larger the land size, the more crop production if all other factors remain constant. The direct relationship between land size and food security is consistent with previous studies (Tasokwa, 2011; Pankomera *et al.,* 2009; Amwata, 2004). However, a study such as Matchaya (2007) has reported an inverse relationship between farm size and production in agricultural sector of Malawi. He noted his finding to be unusual but argued that the outcome may have been caused by use of total farm output than crop yield. Tasokwa (2011) further explains that there are more to land than size. From her study in Malawi, there are sub-factors that influence the size of land owned by a household, which include gender, age of the household head, social networks, marital status and culture and traditions.

Livestock presented in tropical livestock units per adult equivalent had a negative and significant influence ($p \leq 0.10$) on Makueni County household food security status. This finding implies that the larger the number of livestock owned, the more vulnerable was the household to food insecurity. The likely explanation was that in agropastoral areas like Makueni County, grazing land has become limited due to rapidly expanding population and agricultural land, thus reducing grazing areas, resulting in losses in livestock.

Rainfall has a positive and significant ($p \leq 0.05$) influence on household food security in Makueni County. Areas receiving more rainfall tend to have high crop and forage production. According to Hesselberb and Yaro (2006); Assan *et al*. (2009) and Tasokwa (2011), climatic variability, especially rainfall fluctuations, is a major constraint to agricultural livelihoods.

7.4.2.3 SEM Results for Kajiado County

First a test for endogeneity was carried out in two steps. These steps are shown below.

Step 1: Regress each of the endogenous variables on all the exogenous variables in the model to obtain estimated endogenous variables (size of the herd (Sh), land size (Ls) and household size (Hs) as shown in Table 7.7, a test for endogeinity. The correlation matrix for Kajiado County endogeinity test is shown in Table 7.8. The results show that at 5 per cent level of significance, the coefficient of residuals for household size (-0.236) is statistically significant, indicating the presence of simultaneity problem.

Step 2**:** Regress the dependent variables on all the endogenous variables (Y_2, Y_3 and Y_4), fitted endogenous variables (Y_2*, Y_3* and Y_4*) and exogenous variables (X_k) and conduct F-test to test the hypothesis that the coefficients of the estimated endogenous variables are equal to zero. If the hypothesis is rejected, the endogenous variables are truly endogenous. Tables 7.9 and 7.10 present the correlation and coefficients of the variables used and 2SLS results for Kajiado County. The results are based on the objective addressing the determining factors of household vulnerability to food insecurity.

Table 7.7: Coefficients for Kajiado County (test for endogeneity)

Variable	Coefficient	t value
Constant		-1.727*
Gender of the household head	0.165	2.063**
Age of the household head	0.070	0.844
Household access to climate information	0.254	3.025**
Source of climate information	0.045	0.518
Off farm income	0.541	6.387**
Residuals for household size	-0.236	-2.994**
Residuals for land size	0.076	0.936
Experience in the area	0.150	1.734*

**** Significant at p≤0.05, * Significant at p≤0.10**
F = 9.228 (p≤0.05)

Table 7.8: Correlation Matrix for Kajiado County (test for endogeinity)

Variables	Experience in an area	Residuals for household size	Residuals for land size	Gender of household head	Access to climate information	Age of household head	Off farm income	Source of climate information
Experience in an area	1.000							
Residuals for household size	-0.008	1.000						
Residuals for land size	0.046	0.085	1.000					
Gender of household head	0.126	-0.001	0.008	1.000				
Access to climate information	0.001	0.009	-0.053	0.038	1.000			
Age of household head	-0.283	0.002	-0.013	-0.154	-0.016	1.000		
Off-farm income	0.175	-0.045	0.264	0.029	-0.201	-0.050	1.000	
Source of climate information	0.292	-0.009	0.053	-0.052	-0.306	-0.111	0.202	1.000

Table 7.9: SEM Regression Results for Kajiado County

Variable	Coefficient	t-value
Constant		-1.753*
Land size per household in acres	0.071	0.797
Herd size in TLU	-0.152	-1.756*
Household access to climate information	0.348	2.993**
Source of climate information	-0.015	-0.139
Fitted household size	0.234	1.180
Education levels of household head	0.050	0.489
Off-farm income	0.522	5.871**
Experience in years lived	0.030	0.174
Gender of the household head	0.225	2.492**

****Significant at $p \leq 0.05$, *Significant at $p \leq 0.10$**
Adjusted $R^2 = 0.354$, $F = 6.908$ ($p \leq 0.05$)

Household access to climate information has a positive and significant ($p \leq 0.05$) influence on household vulnerability to food insecurity in Kajiado County. Climate information is essential in areas, which are affected by climate variability. Climate information access enables rural households to plan their land-use activities, especially when to move with their livestock depending on the weather conditions for that particular year. Therefore, households with access to climate information are likely to plan their land-use activities such as where to graze livestock, when to plant and type of crops to be planted. In support, a study by Ziervogel (2004) in Lesotho and Tasokwa (2011) in Malawi found out that small holder farmers who had access to climate information were able to plan for their land-use activities particularly when to plant and the type of crops to grow.

Herd size has a negative and significant ($p \leq 0.05$) influence on household food security status. This implies that households that have large herds of livestock are more likely to be vulnerable to food insecurity. The explanation is that most of the pastoral areas were communally owned during the pre-colonial and colonial periods, which allowed for mobility to access the forage resources. However, due to expansion of population and settlement, modernisation and individualisation of land tenure, the grazing resources have diminished such that they cannot support large herd sizes.

Table 7.10: Correlation Matrix for Kajiado County SEM Regression

Variable	Herd size in TLU	Gender of household head	Off farm income	Education of household head	access to climate information	Land size in acres	Source of climate information	Experience in years	Fitted household size
Herd size in TLU	1.000								
Gender of household head	-0.101	1.000							
Off farm income	0.055	0.068	1.000						
Education levels of household head	-0.018	0.277	0.090	1.000					
Access to climate information	-0.155	0.254	-0.131	0.156	1.000				
Land size in acres	0.060	0.158	0.296	0.220	0.031	1.000			
Sources of climate information	0.164	-0.250	0.161	-0.362	-0.484	0.037	1.000		
Experience in years	0.193	-0.205	0.116	-0.035	-0.557	0.120	0.449	1.000	
Fitted household size	-0.271	0.358	0.015	0.291	0.660	0.052	-0.453	-0.829	1.000

Gender of the household head has a positive and significant ($p \leq 0.05$) influence on household vulnerability to food insecurity. Female headed households were more food secure than their male counterparts in Kajiado County. The finding supports previous studies such as Kennedy and Haddad (1994), Carter (1997) and Nyariki *et al.* (2002) in which women were found to be food secure due to the fact that they prioritise their income on food for their families than men. However, this outcome contradicts that of Tasokwa (2011), who noted that female headed households were more food insecure due to associated cultural beliefs where access to resources for food production such as land and inputs is low.

Off-farm income has a positive and significant ($p \leq 0.05$) influence on household vulnerability to food insecurity in Kajiado County. This means that households without access to off-farm income were more likely to be food insecure. Off-farm employment is a source of income that can be used to purchase food, although the money raised from it may have other priorities. Similar findings have also been reported by Reardon (1997), Ellis (2000) and Bryceson (2004). Moreover, Barrett *et al.* (2001) underscores the positive relationship among off-farm diversification, income and wealth in rural Africa. He stated that these three interactions offer an opportunity out of poverty in the continent. Further, he expounded that livelihood diversification, involving off-farm activities has over the years become an important poverty reduction and income generating strategy for peasants and rural small farm households especially in vulnerable and marginal environments throughout the developing world.

Other variables that were hypothesised to influence household vulnerability to food insecurity in Kajiado County but were insignificant at $p \leq 0.05$ were education of the household head, land size, sources of climate information, household size and years of experience in the area.

7.5 CONCLUSION AND RECOMMENDATION

7.5.1 CONCLUSION

This study has shown that both farm and household characteristics interact jointly to influence household vulnerability to food insecurity. In Makueni County, the main determinants of household vulnerability to food insecurity were land size, household size, rainfall levels and herd size. The finding noted that in Makueni County, households located in high rainfall areas with large tracks of land, large household sizes and small herd sizes were less vulnerable to food insecurity. For Kajiado County, the determinants of household food security were gender of the household head, access to climate information, off-farm employment and herd size. This implies that households with access to climate information, more income from off-farm employment, small herd sizes and headed by female were less vulnerable to food insecurity. For households in both counties, herd size had a negative significant $p \leq 0.05$ influence on household vulnerability to food insecurity, implying that households with small herd sizes were likely to be more food secure. The probable explanation is that currently there is increased conversion of grazing areas into cultivation or settlement, and with individualisation of tenure, more of the grazing land is being converted to non-grazing uses. Thus, there are very limited grazing resources to support large herds of livestock.

Policy interventions in the ASALs need to emphasise a systems approach to by taking into consideration different land production systems. For instance, in Makueni County, predominantly an agropastoral area, the initiatives on food security should focus on promoting access to land resources and diversification of livelihoods as a means of destocking large livestock herds. Similarly, innovative programmes that have potential to improve the micro-climate such as agroforestry, especially multipurpose trees and shrubs, should be promoted so as to attract more rains as well as provide ecosystem services. Even though household size has shown a positive influence on food security, studies have shown that this is applicable if members of the household contribute to resource generation. According to Kigutha *et al.* (1994) and Kavishe and Mushi (1993), a large household size favours resource contribution to the household. As such, there is more food available for household consumption and, consequently, an improvement in the nutritional status of the household members. They further argued that in cases where the dependency ratio is high, the number of consumers of the available resources in the household is more than the number of contributors; hence, less is available to share among them, negatively affecting their nutritional well-being.

Although these results are specific and relevant for Makueni and Kajiado Counties, these findings can be used as a case study for other areas with similar conditions and culture. In conclusion diversification into off-farm sources, improved breeding programmes, strengthening of extension services, agroforestry and reafforestation programmes, family planning initiatives and women empowerment are key to minimising household vulnerability to food insecurity in the southern rangelands of Kenya.

7.5.2 RECOMMENDATIONS

From this study, the recommendations to help reduce household vulnerability to food insecurity in the study area are divided into three: these are general recommendations cutting across Kajiado and Makueni Counties, and those specific to Kajiado and Makueni Counties.

7.5.2.1 General Recommendations

The general recommendations for both counties are presented below.

1. Strengthening extension services is fundamental for both Kajiado and Makueni Counties. For households in Kajiado County, it will enable them acquire skills on better livestock management practises, including enhancing their access to climate information that will enable them plan their land-use activities in an effective and efficient manner.

2. Promote breed improvement programmes in both Kajiado and Makueni Counties. to help upgrade the local breeds for drought tolerance and increased production.

3. Foster partnerships and collaboration between agropastoralists, transhumant pastoralists and climate information producers. This will help the climate information producers understand the needs of these households in terms of climate information as well as learn from them. This can be achieved though meetings, symposiums, workshops, open field days and exchange visits.

7.5.2.2 Kajiado County

In Kajiado County, the gender of the household head, access to climate information, off-farm employment and herd size were critical for household food security status. Thus policy interventions need to:

1. Promote women empowerment in order to increase their access to and control over production resources. This will enable women increase their participation in income generating activities. As noted in the current study, increasing women's access to resources including income, increases women's access to food, thus, reduced household vulnerability to food insecurity. Women prioritise provision of food to their households. This can be achieved by formation of women groups to provide forum for sharing ideas and teamwork, and strengthening women micro-finance trusts.

2. There is need for establishment of alternative livelihood sources that are compatible with transhumance in Kajiado County so as to improve on the total household income. These should include activities such as establishment of micro-industries for hides and skins, milk processing plants to provide ready market to avoid exploitation by middlemen. Also, these industries will create jobs opportunities, thereby minimising rural-urban migration in the county.

7.5.2.2 Makueni County

The interventions to reduce vulnerability to food insecurity in Makueni County are presented below.

1. Promote agroforestry and tree planting programmes to help conserve soil and water in Makueni County. Also, this has multiple benefits such as creation of micro-climate and attracting rains.

2. Promote family planning programmes to the households to ensure household dependency ratio is minimal.

3. Facilitate households to have access to land resources and enhance opportunities for improved land production. This can be achieved through provision of inputs such as fertilizers and capital, farm mechanization and ensuring ready market.

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CHAPTER EIGHT

USE OF TIME SERIES DATA TO ESTIMATE THE DETERMINANTS OF FOOD SECURITY IN THE SOUTHERN RANGELANDS OF KENYA

8.1 SUMMARY

Climate variability has increasingly become an important consideration in efforts aimed at ensuring food security for populations that mainly depend on climate for their livelihoods. In Kenya, livestock and crop production is central to total income. Livestock contributes 78.2 per cent and 38.3 per cent of the county income for Kajiado and Makueni Counties respectively. Similarly, crop production contributes the greatest contribution, 52.7 per cent of the total income for Makueni County and only 6.9 per cent for Kajiado County.

Total income refers to the amount of money or its equivalent received during a period of time in exchange for labour or services, from the sale of goods or property, or as profit from financial investments. It is obtained by computing all the different income sources that contribute to the county's consumption and production, then dividing by the total county population in terms of adult equivalents. Its unit of measure is Kenya shillings per adult equivalent. The income sources for the two counties include livestock production and sales, employment, remittance, petty trade, crop sales, crop production and remittances. Most of these activities are dependent on climate. Therefore, climate information, both conventional and traditional is important in influencing total income of a county. This study was conducted in Kajiado and Makueni Counties of Kenya to determine the influence of climatic factors, among other factors, on total income. Time series data covering 31 years were used. Ordinary Least Squares (OLS), Autoregressive, and General Least Squares (GLS) models were used to establish the determinants of total income for each county under different climatic, land-use and socio-economic conditions. GLS model was found to be the most appropriate based on the number of significant variables and the estimated R^2 value. The results showed that rainfall, temperature, rain days, beef and maize prices influence total income in both Kajiado and Makueni Counties. These results suggest that initiatives that help regulate beef and maize prices are essential in ensuring predictable market prices and sustainable income. Besides, creation of micro-climate through reforestation and agroforestry programmes offers opportunities to moderate the temperatures as well attract more rainfall. Also, forests have

potentials to provide other co-benefits such as acting as carbon sinks to mitigate climate change. Other benefits include food, timber, raw materials for industries and employment.

8.2 INTRODUCTION

Agriculture is the backbone of most African economies, the largest contributor to gross domestic product (GDP), accounts for about 40 per cent of the continent's foreign currency earnings, and the main generator of savings and tax revenues (NEPAD, 2002). In addition, about two-thirds of manufacturing value-added is based on agricultural raw materials. Thus, agriculture is crucial for pro-poor economic growth in Africa, as it supports 70 to 80 per cent of the rural population. Therefore, more than in any other sector, improvements in agricultural performance have the potential to increase rural incomes and purchasing power for large numbers of people to lift them out of poverty (NEPAD, 2002; Wiggins, 2006).

As in many countries in Africa, agriculture is the mainstay of Kenya's economy, and contributes 26 per cent of the GDP directly and another 25 per cent indirectly. Also, the sector accounts for 65 per cent of Kenya's total exports and provides more than 18 per cent of formal employment. For instance, more than 70 per cent of informal employment is in the rural areas (ROK, 2010). The sector is dominated by the production of cash crops, food crops and livestock for local consumption. The livestock sub-sector alone contributes about 50 per cent of the country's GDP, provides 90 per cent of employment and more than 95 per cent of household incomes in the arid and semi-arid lands (ASALs) (Nyariki, 2008). Furthermore, it is estimated that Kenya's potential to export livestock products if adequately exploited would earn more than the earnings from tea and coffee combined. Despite the role of this sector in the country's economic growth, it only receives 10 per cent of the government's agricultural expenditure and less than one per cent of total spending (Nyariki *et al.*, 2005).

The limited attention given to the agricultural sector could be attributed to conflicting set of policy objectives and regulatory frameworks. Therefore, Kenya's long-term goal of food self-sufficiency remains unmet. Frequent droughts precipitate requests for donor-provided food aid to mitigate the ravages of famine, especially in the arid and semi-arid regions, inhabited largely by pastoral tribes. With a population of more than 38 million people (about ten per cent of whom are classified as food insecure) and growing at an annual rate of about three per cent, Kenya is the largest import market for food and agricultural products in East Africa.

The country imported about USD 725 million in agricultural products during 2009, up from about USD 525 million in 2007 in an attempt to mitigate food crisis (USDA, 2009).

The food price crisis of 2008 has led to the re-emergence of debates about global food security and its impact on prospects for achieving the first Millennium Development Goal (MDG): to end poverty and hunger (Jaspars and Wiggins, 2009). In addition to a number of shorter-term triggers leading to volatile food prices, the longer-term negative impacts of climate variability and change need to be taken very seriously (Ludi, 2009). In January 9, 2009, the Government of Kenya declared a food emergency, stating that about 10 million Kenyans, or about 25 per cent of the population, were to be at risk of food shortage. The estimated 10 million include both those who do not have the financial resources to buy food locally and those who can buy food if available at reasonable prices (USDA, 2009).

Food security is defined as a situation when all people, at all times, have physical, social and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life (Tasokwa, 2011; FAO, 2002). Food security is not narrowly defined as whether food is available, but whether the monetary and non-monetary resources at the disposal of the population are sufficient to allow everyone access to adequate quantities and qualities of food (Ludi, 2009). All dimensions of food security are likely to be affected by climate variability and change. More generally, food security will depend not only on climate and socio-economic impacts on food production, but also on economic growth, changes to trade flows, stocks, and food aid policy.

Climate variability and change pose the greatest threat to agriculture and food security in the 21st century, particularly in many of the poor, agriculture-based countries of sub-Saharan Africa (SSA) with their low capacity to effectively cope (Shah *et al.,* 2008; Nellemann *et al.,* 2009). African agriculture is already under stress as a result of population increase, industrialisation, urbanisation, and competition over resource use, degradation of resources, and insufficient public spending for rural infrastructure and services. The impact of climate variability and change is likely to exacerbate these stresses even further (Ludi, 2009).

Food security is a human right, yet 70 per cent of dryland communities in Kenya live below the poverty line and are therefore prone to food insecurity. Climate variability and change have pushed some medium rainfall areas to rainfall deficient zones, making them food deficit regions. Additionally, some areas with good rainfall still suffer from food insecurity due to inadequate technologies and information that could make them food secure. The production of adequate food, without damaging the environment, becomes an important undertaking that would sustainably secure the future for these communities.

The current food situation in Kenya is drastically different from that of the mid 1970s. Much effort has been geared towards increasing food production in order to cope with the worsening food shortages faced due to increasing climate variability and change in the era of rapidly growing human population (ROK, 2012). Policies aimed at increasing agricultural production have been stressed and many of the modern improved agricultural technologies have contributed to hunger reduction efforts (Kennedy and Haddad, 1994). For instance, increased agriculture and employment through lower food prices and non-agricultural employment have contributed to hunger reduction efforts (Kigutha *et al.*, 1994). Despite these efforts, nearly half of Kenya's population still lives in poverty with concomitant food insecurity and dependency on external food aid. With climate variability and change challenges, underperformance of the agricultural sector, degradation of natural resources, unexploited land-use, lack of markets, and inadequate value-addition, coupled with population pressure, the population segment suffering from poverty and hunger continues to rise (ROK, 2012).

The problem of food security at the micro level is formulated in different ways and the focus is not always set narrowly on food. Maxwell (1990) defines food security as a proxy for poverty. Some writers have gone further to argue that poverty is the central focal point and that food security must be seen as only one aspect of poverty. Likewise, Robinson (1994) argues that the use of food security approach imparts a biased or partial understanding of poverty by neglecting aspects such as asset holding or dependency, or might lead to over emphasis on consumption-oriented interventions. Thus, given the impartiality of food security approach, the current study adopts the use of poverty approach with income per adult equivalent as a measure of food security. Besides, vulnerability cannot be measured in real terms; therefore food security will be used as a proxy. The argument is that for the vulnerable households, access to food is the first and foremost priority, whether from their own production or from purchase. Similar approaches have been used by Maxwell (1990), Kristjanson *et al.* (2002) and Ludi (2009).

8.3 STUDY AREA AND DATA COLLECTION

The data for this study were collected from Makueni and Kajiado Counties of Kenya. The two counties are located in the southern rangelands of Kenya. Kajiado County covers approximately 21,909.9 km^2 and has a human population of 687,312 people (ROK, 2009). It lies between longitudes 36º 5' and 37º 5' east and 1º 0' and 3º 0' south. Both counties are classified by the Kenya Government as arid and semi-arid and are characterised by variable and unpredictable rainfall patterns, dry spells and frequent droughts. Most of Kajiado County lies in semi-arid and arid zones V and VI. Only 8 per cent of the county's land is classified as having some potential for rain-fed cropping (zone IV). Most of this is in the Athi-Kapiti Plains, close to Nairobi, and in the south of the County, along the Kilimanjaro foothills. The mean annual rainfall ranges from 300 to 800 mm. Rainfall is bimodal with short rains being received from October to December and long rains from March to May. The distribution of rainfall between the two seasons changes gradually from east to west across Kajiado County (de Leeuw *et al.,* 1984). In eastern Kajiado, more rain falls during the short rains than during the long rains. In contrast, most rain falls during the long rains in western Kajiado County. Short rains are more reliable in time than long rains and are therefore more important.

Makueni County lies between latitude 1°35′S and longitude 37°10′ and 38°30′E and covers an area of 7,965.8 km^2 (ROK, 2009; 1994). The county borders Kitui to the east, Taita-Taveta to the south, Kajiado to the west and Machakos to the north. In the north the county is hilly with elevations of up to 1,900 m, from which there is a downward slope to the south-east where it forms an undulating plateau at about 700 m. The Makueni County climate is typically semi-arid. As one moves down the slope, so rainfall diminishes from an annual average of 1,300 mm in the northern hills to as little as 500 mm in the south, while temperature and evapo-transpiration rise. Temperature ranges between 12ºC and 28ºC (Gichuki, 2000). The average annual rainfall, evaporation and temperature are in the order of 600 mm, 2,000 mm, and 23°C respectively (Gichuki, 2000; Musimba *et al.,* 2004). This gives a wide range of agro-ecological zones, from the hills where coffee may be grown, to the lower plateau perhaps best suited to grazing livestock but where crops may be planted at the risk of frequent harvest failures. The rainfall regime is bimodal, with 'long' rains falling in March to May and 'short rains' in October to December, giving two cropping seasons. The main food crops for both counties include maize, beans, and pigeon peas while cereals such as millet and sorghum are also grown. The county has a population of 884,527 (ROK, 2009) that grows annually at 2.8 per cent. The population in the area is composed of small-holder subsistence farmers and/or livestock keepers who wholly depend on rainfall for their livelihood.

8.4 METHODOLOGY

Climate has spatial characteristics and is highly variable in Kenya. As a result, it requires site specific data for proper understanding of its influence with respect to the associated parameters of rainfall, rain days and temperature. Time series data were collected from various publications, Ministry of Agriculture, Ministry of Livestock and Fisheries, National Statistics Office, Department of Meteorology, Food and Agriculture Organisation Statistical Database (FAOSTAT), and relevant technical reports. Data for a period of 31 years, from 1980-2010, were collected on livestock numbers, prices received for sale of maize and livestock, remittances, wages, annual rainfall amounts, rain days, annual maize production, area under maize, human population, stocking rate and livestock offtake. Climate parameters were computed using the daily and monthly records. Variables relating to livestock production were obtained by using comparative data based on animal units (For details see Nyariki, 2008).

In formulating the model, various variables that were hypothesised to influence the counties' vulnerability to food insecurity were selected *a priori.* A preliminary correlation analysis was carried out, and an appropriate choice was made between those variables that were found to be highly correlated. The variables used in the final regression include total income per adult equivalent, livestock offtake per hectare, per cent livestock offtake, maize prices, beef prices, human population, land area under maize production, annual rainfall, rain days, temperature, stocking rate and drought as a shift dummy. These variables are discussed below.

8.4.1 Total Income per Adult Equivalent

This is the dependent variable and is defined as the net flows from household assets including land, labour, livestock, entrepreneurship, and relationships. This includes non-marketed food production and remittances as part of income (Walker and Ryan, 1990; Kimuyu *et al.*, 1994). Total county income was derived as the sum of proceeds earned from farm production, employment and business by county members each year. Also, remittances from county members residing away from their households and pension accruing to retired county members were also included. This was then divided by the number of individuals in the county in terms of adult equivalents per year for each county to obtain total income per adult equivalent per year. The county population for each year was converted into adult equivalents based on the annual population structure (Nyariki *et al.*, 2002; Tasokwa, 2011).

Many studies have used income as a measure of vulnerability to food insecurity. For example, FAO (2012) used income and consumption patterns as a measure of food security in Gaza and West Bank of Palestine. This study established that households with low income per adult equivalents (USD 3.1) were more vulnerable to food insecurity than households with higher income per adult equivalents (USD 12). Therefore, the current study hypothesises an inverse relationship between total income per adult equivalent and vulnerability of households to food insecurity.

8.4.2 Rainfall Amounts

The potential impact of rainfall on food security has been examined by various scholars: Downing (1992) for Kenya and Zimbabwe; and Tasokwa (2011) for Malawi. In these studies, rainfall (distribution and amounts) was reported as the most critical for rain-fed agricultural production system. Likewise, Nyariki (2008) documented the influence of rainfall on agricultural productivity and availability of pastures, with rainfall fluctuations as a major constraint to agricultural livelihoods. In addition, estimates of livestock carrying capacity are usually derived directly from rainfall parameters and are linked to vegetative productivity. According to de Leeuw *et al.*(1984), average livestock carrying capacity increases from about 7 ha/tropical livestock unit (TLU) in the south of Kajiado County that has an average annual rainfall of 300 mm to about 3 ha/TLU in the north of the county that has an average annual rainfall of 550 mm. In line with these previous studies, the current study hypothesises that more rainfall means more grazing resources and/or increased maize production, thus increasing household income and the ability to purchase more food, leading to reduced vulnerability to food insecurity.

8.4.3 Rain Days

The number of rain days is critical in most agricultural systems. This is more so in Kenya where agriculture is rain-fed. Besides, rain days are fundamental for crop production. As established by Tasokwa (2011), the distribution of rain days and total annual rainfall were important for maize production in Malawi. The current study presents the distribution of rainfall in terms of the number of rain days per year. Thus, the study hypothesises that more rain days would lead to more maize production and better pastures, thereby increasing total income per adult equivalent.

8.4.4 Mean Annual Temperature

The intensity of temperature plays an important role in determining water balance as it regulates evapo-transpiration. Annual mean temperature was used to assess its influence on total income. It was hypothesised that high temperature has a negative influence on total income per adult equivalent.

8.4.5 Drought as a Shift Dummy

Drought influences total income and the food security of households. Nyariki (2008) observed that in Laikipia District in Kenya, years that had large upswings in livestock offtake were drought years (rainfall of less than 300 mm/year), while the years of downswings had good rain. These swings necessitated the use of a shift dummy in an attempt to take care of dramatic changes in total income per adult equivalent, thus:

$$D_{0t} = \begin{cases} 0, \text{if observed t is a drought} \\ 1, \text{ if otherwise} \end{cases}$$

$$D_{1t} = \begin{cases} 0, \text{if observed t is a drought} \\ 1, \text{if otherwise} \end{cases}$$

Where D is the dummy and t is the year of observation.

8.4.6 Maize Production

The most common food crops in both counties are maize and beans. Data were obtained on maize in terms of production per hectare, total production, sales and consumption from 1980-2010. Maize was chosen to represent crop production since it was the main staple crop grown by almost all households in both counties. Besides, maize had more consistent data over the period of study. This study hypothesises that more maize production leads to higher household income.

8.4.7 Ratio of Area under Maize to Total Cultivated Area

Maize is the main staple food in Kenya including the arid and semi-arid areas. Therefore, the greater the ratio of area under maize, the more maize is produced by the counties. Besides, maize is the most preferred cereal crop, and on average Kenyans depends on maize for almost 50 per cent of their daily caloric intake (USDA, 2009). The hypothesis is that the bigger the ratio of area under maize, the more the county income.

8.4.8 Livestock Offtake

Livestock offtake is an important measure for estimating output from a livestock production unit. The various forms of livestock-related offtake include live animals, milk, meat, hides, skins, and manure. Offtake may thus be seen as removal of live animals or their products from the herd for consumption within a household or a ranch or for the market (Heath, 2000; Nyariki, 2008; Nyariki *et al*., 2005). The most important of the livestock offtake is in the live form. Livestock offtake can thus be generally defined as the per cent of the current year's herd that is removed through sales, deaths, gifts, home-slaughter, or even theft (Nyariki *et al*., 2005). This kind of offtake is calculated from the total herd size kept in a year (Nyariki and Munei, 1993).

In order to compute livestock offtake, Livestock units (LU) are derived. LU are standardized animal units to which different ages, types, or species of livestock are related for purposes of matching forage availability to animal requirements (Nyariki, 2008). Usually the unit is taken to be either a 450 kg live weight steer, with a daily dry matter requirement of 10 kg, or a mature zebu with calf at foot weighing 250 kg, with a dry matter requirement of between 6.5

and 8.5 kg. This latter measure is also referred to as tropical livestock unit (TLU) (Grandin and Bekure, 1982; Nyariki, 2008) and was adopted in this study as shown in Table 8.1.
The relationship between other livestock and the standard unit is usually based on relative live weight, where livestock weights cannot be measured directly in the field (Sullivan *et al.*, 1982). On this basis, about 7 sheep or goats are taken as roughly equivalent to one TLU (Dahl and Hjort, 1976; Gittinger, 1982). Livestock offtake was computed for cattle herds, sheep and goats for each county.

Table 8.1: Livestock conversion rates

Species	Type, sex and age	Weight/animal (kg)	Tropical livestock units
Cattle	Cows, bulls and steers over 3 years	350	1.29
	Heifers and steers 1-3 years	200	0.85
	Calves below 1 year	70	0.38
Sheep and goats	Adults (lambs and kids disregarded)	35	0.23
Camels	Cows, bulls and castrates over 5 years	400	1.42
	Immature (1-5 years)	250	1.00
	Calves	50	0.30
Donkeys	Adults only	150	0.68

Source: Nyariki (2008).

Livestock offtake has implications on income, food security, poverty alleviation, and environmental health in various pastoral production systems. Nyariki (2008) noted that in Laikipia District in Kenya, the food security status and livelihoods of the population depend upon livestock offtake. Therefore, the current study hypothesises that changes in livestock offtake would have implications on total income and consequently the food security status of households.

8.4.9 Beef Price

Prices play an important role in agricultural systems. To allow for comparison over the years, beef prices were deflated to obtain real beef prices. In a relatively free market economy such as Kenya's, it is assumed that agricultural producers are rational so that when prices offered are high, they will endeavour to produce for sale. The current study hypothesises that higher beef prices would lead to increased income (Nyariki, 2008).

8.4.10 Maize Price

Maize price is defined as the price a consumer is willing to pay for a kilogramme of maize. Maize prices were also deflated to obtain real maize prices. This study hypothesises that higher maize prices would lead to increased income.

8.4.11 Stocking Rate

Stocking rate is defined as the number of livestock units grazed on an area of land for a given period of time. Correct stocking rate ensures correct intensity of utilisation of available forage, water and other resources, and is therefore both an indicator of the level of capital investment and management quality. Stocking rate is assumed to be directly related to the degree of overgrazing and possible range degradation (Nyariki, 2008). Nyariki (2008) noted a positive effect of stocking rate on household income and food security. However, he further stated that this is only possible if the existing forage would allow extra animals to be kept and it is not a limiting factor. If extra animals are added to an already optimum; stocking rate, the added animals will adversely affect the performance of other animals, causing output to drop (Nyariki, 2008; Veysset *et al.*, 2008).

8.4.12 Human Population

Studies have shown that human population has influence on the agricultural productivity and household income. Jabbar *et al.* (2007) reports that as human population density per square kilometre increases, more grazing land is used for settlement and farmland. But also there might exist a positive relationship between human population and total income. Higher human population implies more labour available to produce more crops and livestock products, and consequently increased total income. This study hypothesises a positive relationship between human population and total income per adult equivalent in Kajiado and Makueni Counties.

8.5 TIME SERIES MODELS

The data available were examined and their application carried out based on the structure of the models. Three models were proposed, namely ordinary Least Squares (OLS), Generalised

Least Squares (GLS) and Autoregressive models. All the three models mentioned above give unbiased and consistent parameter estimates, and the main criterion for discrimination would, therefore, be that of efficiency (Davidson and Mackinnon, 1993; Pindyck and Rubinfeld, 1998; Wooldridge, 2003).

8.5.1 Ordinary Least Squares Estimation

First the OLS was performed on the entire data set. This was based on the assumption that the independent variables and the dependent variable have a uni-directional relationship. The underlying assumption in an OLS is that the relationship between γ and χ is either linear or non-linear. The OLS model may be expressed as follows:

$$\gamma = \alpha + \beta_1 \chi_1 + \beta_2 \chi_2 + ... + \beta_n \chi_n + \in \quad (8.1)$$

Where:

α = Constant term

$\in$ = Error term

$ß_1$, $ß_{2,}$…,$ß_n$= Regression coefficients

$\chi_{1,}$ χ_2,…,χ_n = Independent variables

The specified model used to estimate the determinants of food security in this study was:

$$TY_t = \alpha + \beta_1 DR_t + \beta_2 OF_t + \beta_3 MP + \beta_4 BP_t + \beta_5 SR_t + \beta_6 RF_{t-1} + \beta_7 RF_t + \beta_8 RD_t + \beta_9 MT_t + \beta_{10} MA_t + \in_t \quad (8.2)$$

Where:

TY_t = Total income per adult equivalent for each county at time t

α = Constant term

$ß_1$, $ß_{2,}$… , $ß_n$ = Regression coefficients

DR_t = Drought condition as a dummy for each county at time t

RD_t = Rainfall days for the county at time t

HP_t = Labour in terms of human population for each county at time t

OF_t = Livestock offtake per hectare for the county at time t

MP_t = Real maize prices per year for the county at time t

BP_t = Real beef prices per kilogramme live weight for the county at time t

SR_t = Stocking rate of the livestock per county at time t

RF_{t-1} = Annual rainfall lagged once for each county at time t

$\in$ = Error term for the county at time t

One of the assumptions underlying OLS estimation is that the errors would be uncorrelated. This assumption can easily be violated for time series data. Therefore, if errors are autocorrelated, the OLS estimator can be seriously inefficient.

8.5.2 Generalized Least Squares (GLS) Model

The GLS is a technique for estimating the unknown parameters in a linear regression model. It is applied when the variances of the observations are unequal (heteroscedasticity), or when there is a certain degree of correlation between the observations. In these cases OLS can be statistically inefficient, or even give misleading inferences.

The GLS process has the effect of standardizing the scale of the errors and "de-correlating" them. Since OLS is applied to data with homoscedastic errors, the Gauss–Markov theorem applies, and therefore the GLS estimate is the best linear unbiased estimator for *β.* As opposed to OLS, GLS conducts further test to detect the presence of autocorrelation, through the Durbin Watson statistics and unit root test using the Cochrane-Orcutt procedure, which considers the fact that the error term may be correlated over time (Thomas, 1993; Baltagi, 2001).

The specified GLS model for this study can be written as:

$$TY_{it}^{\Theta} = \alpha(1-p_i) + \beta_1 D_{i,t-1}^{\Theta} + \beta_2 MP_{i,t-1}^{\Theta} + \beta_3 BP_{i,t-1}^{\Theta} + \beta_4 SR_{i,t-1}^{\Theta} + \beta_5 RF_{i,t-1}^{\Theta} + \beta_6 RD_{i,t-1}^{\Theta} + \beta_7 MT_{i,t-1}^{\Theta} + \beta_8 MA_{i,t-1}^{\Theta} + \omega_{it}^{\Theta}$$

(8.3)

Where:

D_t = Drought at time t

MP_t = Maize price per kg at time t

BP_t = Beef price per kg at time t

SR_t = Stocking rate at time t

RF_{t-1}= Rainfall amounts at time t

RD_t = Number of rain days in a year at time t

MT_{t-1} = Maize production in metric tonnes at time t

MA_t = Area under maize production at time t

HL_t = Human labour at time t

ω_t = Error term

θ = Differenced variables and error term

8.5.3 Diagnostic Tests

Two diagnostic tests, Durbin Watson and unit root tests, were carried out to detect the presence of autocorrelation in the GLS model. These tests are described below.

8.5.3.1 Durbin-Watson Statistics

The Durbin-Watson statistic (*d*) is a test statistic used to detect the presence of autocorrelation (a relationship between values separated from each other by a given time lag) in the residuals (prediction errors) from a regression analysis (Durbin, 1950, 1951; Sargan and Bhargava, 1983).

Since *d* is approximately equal to $2(1-r)$, where *r* is the sample autocorrelation of the residuals, $d = 2$ indicates no autocorrelation. The value of *d* always lies between 0 and 4. If the Durbin-Watson statistic is substantially less than 2, there is evidence of positive serial correlation. As a rough rule of thumb, if Durbin-Watson is less than 1.0, there may be cause for alarm. Small values of *d* indicate successive error terms are, on average, close in value to one another, or positively correlated. If $d > 2$, successive error terms are, on average, much different in value to one another, i.e., negatively correlated. In regressions, this can imply an underestimation of the level of statistical significance (Gujarati, 2003).

8.5.3.2 Unit Root Test

Unit root test is a further test of stationarity (or nonstationarity) of the observations. The starting point is the unit root (stochastic) process where:

$$Y_t = \rho Y_{t-1} + u_t \quad -1 \le \rho \le 1 \qquad (8.4)$$

Where u_t is a white noise error term.

We know that if ρ = 1, that is, in the case of the unit root, equation 8.4 becomes a random walk model without drift, which we know is a nonstationary stochastic process. Thus, the need to use Dickey Fuller test to find out if the estimated coefficient of Y_{t-1} in (8.4) is zero or not (For details see Tasokwa, 2011; Nyariki, 2008; Gujarati, 2003).For each independent variable, regress its first level difference against its first order lag to obtain the t-value. Then, compare the t-value generated with the Dickey Fuller (DF) table values as discussed by Nyariki (2008) and Gujarati (2003). If the t-value is greater than the DF value, then the data do not exhibit the random walk.

Before estimating equation (8.3), the unit root tests of stationarity of the variables were carried out. All the variables were found to represent stationary time series at the 5 per cent level of significance. As an illustration, we use the example of annual rainfall. The results were as follows:

1. The Kajiado County total annual rainfall (RF):

$\Delta RF_t = \alpha_1 + \delta RF_{t-1} + \mu_t$

$\Delta RF_{t-1} = 5.801 - 0.0837 RF_{t-1}$ (8.5)

t = (0.837) (-7.942)

$r^2 = 0.700$; $d = 2.139$

2. The Makueni County total annual rainfall (RF):

$\Delta RF_t = 5.801 - 0.0837 RF_{t-1}$ ` (8.6)

t = (0.689) (-5.026)

$r^2 = 0.689$; $d = 1.944$

The results in equations (8.5) and (8.6) show that the error term is not autocorrelated based on Durbin Watson test. Further tests for stationarity of the variables, in this example, total annual rainfall for both Kajiado and Makueni Counties, can be proved by Dickey-Fuller (DF) test using the t-value (tau-statistics). Since the computed tau value for Kajiado County is -5.026 and that for Makueni County is -5.026, both values are greater than 5 per cent critical

DF value of -2.877. Thus data for Kajiado and Makueni Counties did not exhibit random walk.

8.5.4 Autoregressive (AR) Model

There are three broad classes of time series models commonly used. These are the autoregressive (AR) models, the integrated (I) models, and the moving average (MA) models. These models are often intertwined to generate new models. However, our concern is the AR model, discussed below.

In the AR model, the dependent variable is lagged and used as an explanatory variable. For example, an output of a product today may affect its future output, and the current value of the output depends on the previous value. For example, let TY_t represent total income per adult equivalent for Makueni and Kajiado Counties respectively at time *t*. If we model TY_t as

$$TY_{t-\delta}) = \alpha_1 (TY_{t-1-\delta}) + \mu_t \qquad (8.7)$$

where δ is the mean of TY and μ_t is an uncorrelated random error term with zero mean and constant variance σ^2 (i.e., it is white noise), then we say that TY_t follows a first-order autoregressive, or AR (1**)** stochastic process. Hence the value of TY at time *t* depends on its value in the previous time period and a random term; the TY values are expressed as deviations from their mean value. In other words, this model says that the forecast value of TY at time *t* is simply some proportion (= α_1) of its value at time (t-1) plus a random shock or disturbance at time t; again the TY values are expressed around their mean values.

In general, we can have:

$$TY_{t-\delta} = \alpha_1 (TY_{t-1-\delta}) + \alpha_2 (TY_{t-2-\delta}) + \cdots + \alpha_p (TY_{t-p-\delta}) + u_t \qquad (8.8)$$

Where TY_t is a $p^{th\ order}$ autoregressive, or AR (p), process.

The specific autoregression model for this study can be expressed as:

$$TY_t = \lambda + \alpha_1 TY_{t-1} + \alpha_2 RD_t + \alpha_3 DR_t + \alpha_4 HP_t + \alpha_5 OF_t + \alpha_6 MZ_t + \alpha_7 BP_t + \alpha_8 RF_{t-1} + \alpha_9 SR_t + \varepsilon_t \qquad (8.9)$$

Where:

TY_t = Total income per adult equivalent at time t

TY_{t-1} = Total income per adult equivalent lagged once at time t

λ = Constant term

$\alpha_1, \alpha_2, \ldots, \alpha_n$ = Regression coefficients

DR_t = Drought condition as a dummy for each county at time t

RD_t = Rainfall days for the county at time t

HP_t = Labour in terms of human population for each county at time t

OF_t = Offtake per unit area for the county at time t

MP_t = Maize prices per year for the county at time t

BP_t = Real beef prices per kilogramme live weight for the county at time t

SR_t = Stocking rate for the livestock per county at time t

RF_{t-1} = Lags in annual rainfall amounts for the county at time t

$\in_t$ = Error term for the county

8.6 RESULTS AND DISCUSSION

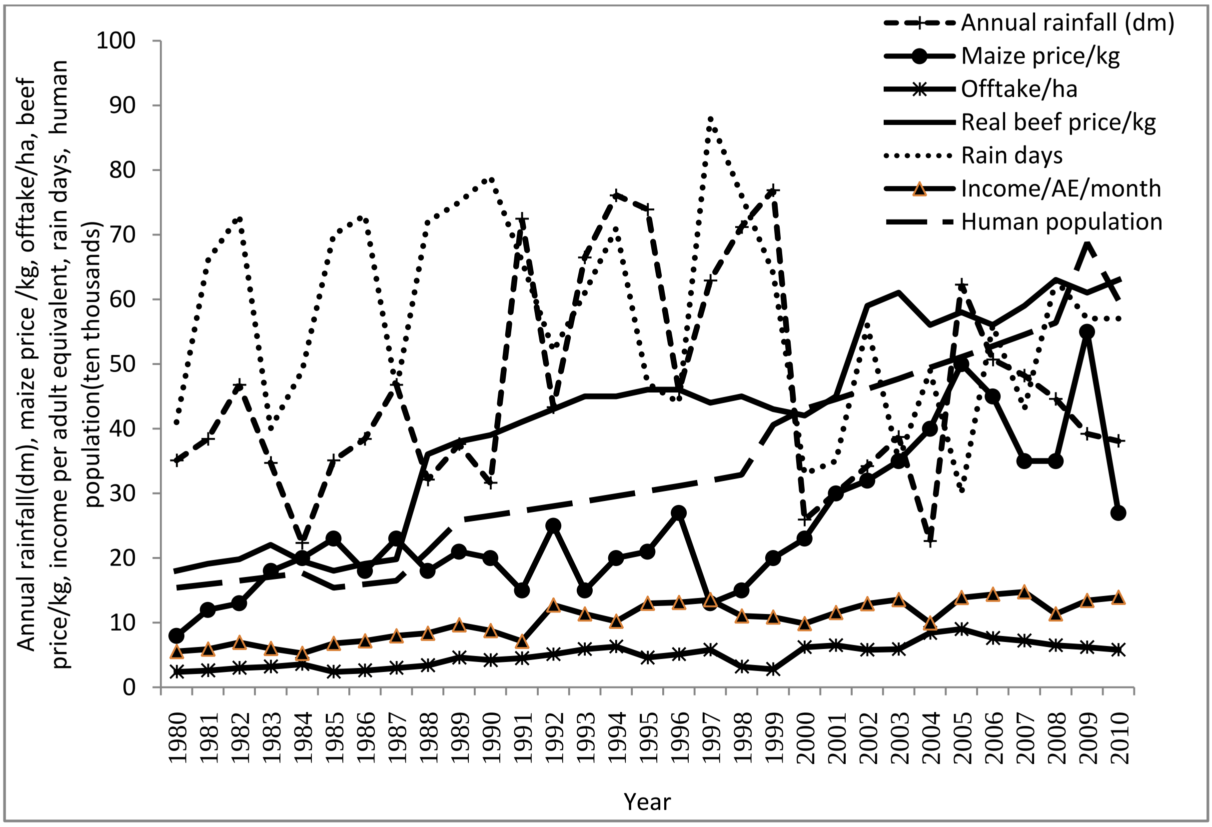
Before discussing the results of the regression analysis, it is of interest to present some of the data of the descriptive analysis (Table 8.2). Both regression and descriptive analyses were conducted separately based on the data gathered.

8.6.1 Descriptive Analysis

The trends in some of the variables used for time series analysis are presented in Figure 8.1, 8.2 and Annex 3. The time series data indicate that per cent livestock offtake ranged between 14.1 per cent in 1980 and 41.9 per cent in 2009 in Kajiado and Makueni Counties. The 41.9 per cent noted in 2009 remains abnormally high and the most probable reason is that data was based on projection through series mean, which may have been misleading. The low per cent livestock offtake of mid 1980s would have been mainly caused by the droughts of 1983/84, a period in which some of the lowest stocking rates were registered. The situation is repeated immediately after 1991/1992 and 1995/96 periods, which were also periods of drought. Stocking rate has shown a similar trend in both counties, an increasing trend, but with a slight decline in the drought or flood years. For example, beef prices showed an upward trend from 1980 to 1983, but declined in 1984. Then, the beef prices started increasing from 1986 to

1996, but declined in 1997/1998. The periods of beef price decline corresponds with years of climate extreme events. For example, the decline noted in 1983/1984, 1991/1992, 1995/1996 corresponds with periods of drought reported countrywide including Kajiado and Makueni Counties. Similarly, in 1997/1998, there was *El Niño* rain that resulted in flooding; thus pastures were inadequate. This may have been coupled with diseases associated with dampness such as pneumonia and foot rot, leading to losses in livestock, thereby reducing the total income.

Figure 8.1: Trends in offtake, annual rainfall, rain days, beef prices, maize prices, human population and income per adult equivalent in Kajiado County, 1980-2010



Source of Data: KIPPRA (2010); Kajiado Meteorological Station, Kajiado District Development Plans (1994-1998; 1998-2002; 2002-2008; 2008-2012); Kajiado District Ministry of Agriculture and Livestock Annual Reports, 1990-2010).

Climate factors play an important role in determining agricultural production in the ASALs of Kenya. The ASALs are characterised by a low and highly variable distribution of rainfall spatially and over time, which limits the potential for crop yields. The amount of rainfall and its distribution over the year greatly affects the productivity of agriculture in these regions. It determines the types of crops to be grown, the presence or absence of support activities like irrigation and crop yields, as well as influencing agricultural calendar.

Annual rainfall (measured in decimetres) showed some interactions with livestock offtake per ha. From early 1980s to the beginning of 1990s, these two exhibited a similar trend. However, from early 1990s to 2005, both depicted divergent trends, after which they continued to show a more similar trend. The probable explanation for this trend could be that in 1980s to 1990s, rainfall patterns were more predictable and households in Kajiado County were able to adequately plan their land-use activities, especially the number of animals for the market. Conversely, from 1990 to 2004, rainfall became more erratic and unpredictable (shown by zigzag trend); thus with more rainfall, pasture and water were more available, leading to a reduction in livestock offtake. Among the pastoral households, as in the case of Kajiado County, the Maasai tend to hold on to their animals when there is adequate pasture and release fewer to the market. However, during periods of low rainfall or drought, pasture become limited and the Maasai tend to dispose of more of their animals before the animals lose their body condition and in some cases even die.

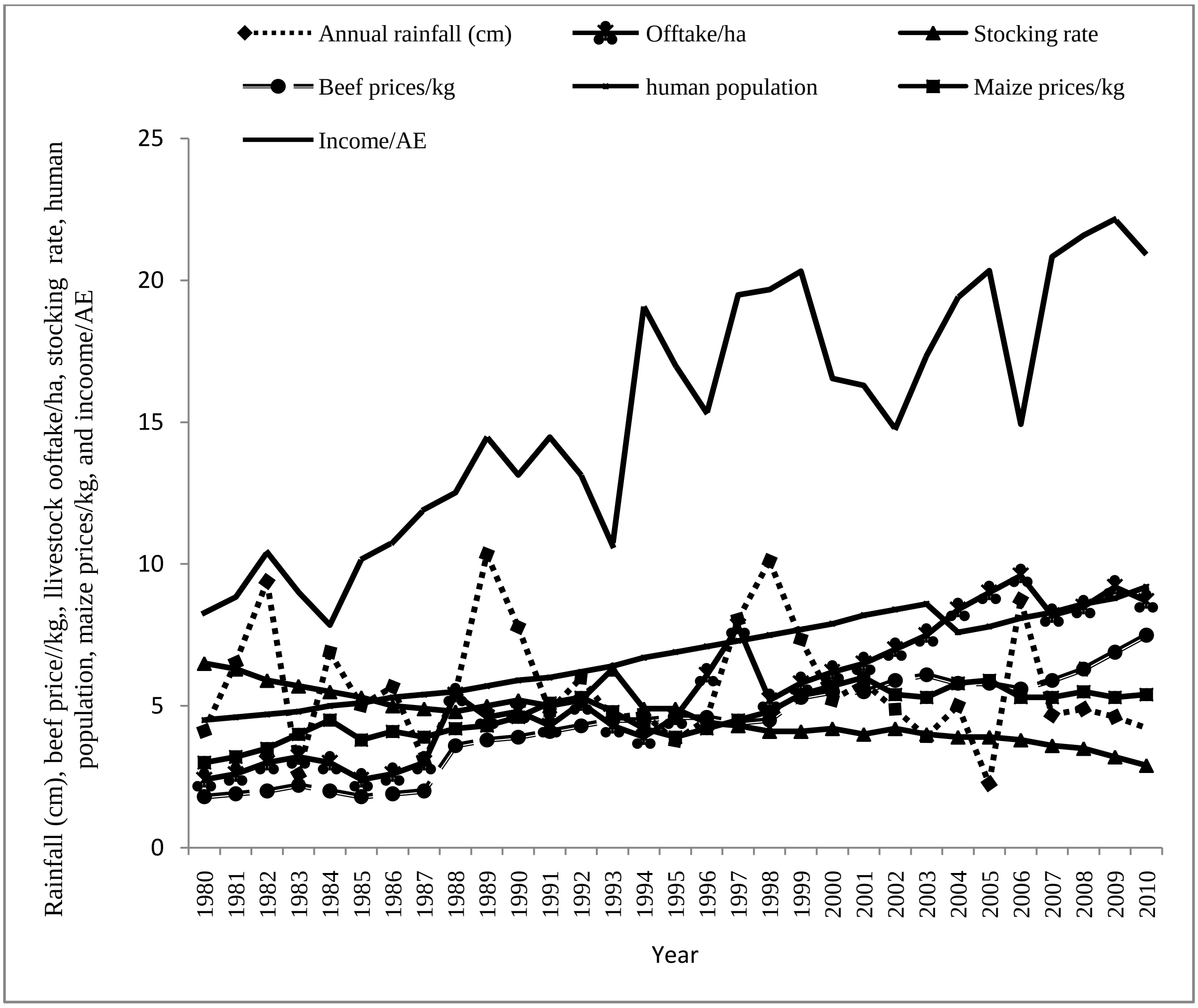
Total income showed no clear relationship with human population. In the early 1980s to 1990s, human population showed some growth, but at a very slow pace. There was a decline in human population in 1985/1986. This was followed by a decline in total income. Similarly, total income has continued to show upward and downward swings. This implies that there are factors other than human population interacting to influence total income.

Beef price per kilogramme has generally shown an increasing trend since the 1980s. The lowest real beef prices were reported in 1984/1985, 1999/2000 and 2004/2005. These years coincide with the drought periods, as reported by Orindi *et al.* (2006). The probable reason could be that when rainfall is adequate, most pastoralists tend to hold on to their livestock and release few animals to the market. Conversely, during drought, many pastoralists sell off their livestock to minimise the devastating effects of drought. This makes beef prices to drop leading to reduced income.

Maize price has been highly variable. From the early 1980s to 1989, maize price per kg was fairly stable but variability has increased since then. The highest maize prices were reported in 1985, 1987, 1992, 1997, 2005 and 2009. These periods correspond to just before drought or just after drought. For instance, the 1983/1984 drought affected agricultural production in 1985; thus maize prices shot up due to reduced maize production. The likely explanation is that climate parameters such as rainfall have a lagging effect and may not affect agricultural production in the same season, but in the future season.

Figure 8.2 shows rainfall as one of the factors closely associated with total income. The two variables have moved together during the period of study. Total income has continued to increase but with down swings in 1984, 1994, 1997/1998, 2001 and 2007. These mentioned downswings in total income correspond to periods of weather extreme events such as droughts (1984, 1994 and 2001) and flooding (1997/1998). However, the decline in income noted in 2007 may have been caused by post election violence that saw many people lose their property and assets, thus reduced income levels.

Figure 8.2: Trends in offtake, annual rainfall, rain days, beef prices, maize prices, human population and income in Makueni County from 1980 to 2010



Source of Data: KIPPRA (2010); DWA, KEFRI, Makindu Meteorological Stations, Makueni District Development Plans (1994-1998; 1998-2002; 2002-2008; 2008-2012); Makueni District Ministry of Agriculture and Livestock Annual Reports, 1993-2010).

Stocking rate has been declining irrespective of the rainfall levels. This implies that there are factors other than rainfall influencing stocking rate. Some of these factors may include size of land holdings, government policies and legislation. On the other hand, human population has shown an upward trend, though a decline was noted in 2004. This decline would not be verified, but one probable reason is that since population census is carried out every 10 years, the 2004 year was a poor estimate.

Real beef and maize prices have also shown some degree of trending with rainfall. When rainfall levels are low, maize and beef prices are high. This can be explained by the fact that during periods of low rainfall, drought limits moisture availability to crops, thus reduced output and total income. For beef, at the onset of drought, prices will be low, since most households will be offering their livestock for sale. However, as the intensity of drought increases, fewer animals are offered for sale, resulting in high beef prices. In addition, the plots of trend showed variability (zig-zag shapes) in annual rainfall, stocking rate, and real maize and beef prices (Figures 8.1 and 8.2). The trends in annual rainfall and maize prices support results from the USA, which showed that high variance in climatic conditions results in greater variability in crop yields and prices (McCarl *et al.*, 2008; Tasokwa, 2011).

Similarly, high livestock offtake per ha were noted in periods of extreme weather events such as droughts (1983/84, 1987, 1992/93 and 2009), and floods (1997/98). This implies that during periods of extreme weather events, households tend to dispose of their animals, and hold on to a few that could be sustained during the period. Also, in the early 1980s, livestock offtake continued to increase with real beef prices and maize prices irrespective of the rains, indicating that prices and other socio-economic factors rather than climate triggered this increase. Likewise, there have been down-swings in livestock offtake, though the general trend has been upward. Figure 8.2 shows that offtake trend closely follows real beef prices. It can be noticed that stocking rate is not influenced by rainfall levels and prices. Land being allocated to stock units is declining compared to 1980s. Further, the year 1994 had the lowest stocking rate, and the likely explanation is that the 1991/1993 drought may have resulted in the death of livestock, thus leading to fewer stock units per hectare.

There was a marked increase in stock per unit land and offtake between 1990 and 2010. In this period real beef prices rose steadily. The rise in real beef prices and the accompanying improvement in both stocking rate and offtake occurred after the liberation of the beef markets in the late 1980s when producer and consumer prices were decontrolled, and at the beginning of the 1990s when a total waiver of controls in the beef and dairy industry in the country took place (ROK, 1996; Nyariki, 2008).

The contribution of different economic activities to the total income per adult equivalent is presented in Table 8.2. In Kajiado County, livestock was the greatest contributor (78.2 per cent) to the total income per adult equivalent with remittance being the least; while for Makueni County, the greatest proportion was from crop production followed by livestock, and the least being remittances.

Table 8.2: Contribution of different economic activities to total income per adult equivalent in Kajiado and Makueni Counties*

Economic activity	Kajiado (Kshs)	Makueni (Kshs)
Farm-based		
Livestock	810 (78.2)	581.0 (38.2)
Crops	71.4 (6.9)	802 (52.7)
Non-farm based		
Employment	117(11.3)	12 (8.2)
Remittances	37.3 (3.6)	14 (0.9)
Total	1,035 (100.0)	1,521 (100.0)

***Figures in brackets are percentages**

Remittances were considerably higher in Kajiado County than Makueni County. The likely explanation is that most households in Kajiado County are livestock keepers, and due to increased frequency of drought, livestock are lost in masses; thus young household members have to search for jobs to support their households. In support, Amwata (2004) reported high remittances in transhumant households than in agropastoral households of Kajiado County.

8.6.2 Regression Results

The descriptive analysis of variables used in regression analysis are summarised in Table 8.3. The climate factors represented in the models include mean annual rainfall, rain days and mean annual temperature.

The total income per adult equivalent was higher for Makueni County (Kshs 1,521), which is predominantly agropastoral, and lower for Kajiado County (Kshs 1,034 per adult equivalent), a typical pastoral setting. Comparing these values to the recommended rural poverty line of Kshs 1,239 per adult equivalent (Kristjanson *et al.*, 2002), Makueni County households were likely to be less vulnerable to food insecurity than their counterparts in Kajiado County. The likely explanation is that Makueni County is a predominantly mixed farming area, growing both crops and livestock. When crop yields are not guaranteed, these households can sell their animals to purchase cereals to meet their dietary requirements. Moreover, either crops or livestock provide insurance against each other during climate extreme events. For instance, when prices of cereals are expected to increase due to climate extremes such as drought, farmers in Makueni County may hold on to their cereals and use it for consumption rather than sell. Conversely, for Kajiado County, when there is drought, pastures become limited and livestock are often sold at through away price. At this time, cereal prices become very high. This reduces the purchasing power of households thereby increasing their vulnerability to food insecurity.

Table 8.3: Summary of variables in the regression analysis

Variable	Kajiado				Makueni		
	Unit definition	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Dependent Variable							
Total income per adult equivalent	Kenya shillings	1,034.0	523.0	1,477.0	1,521.0	785.0	2,216.0
Explanatory Variables							
Total annual rainfall	Decimetre (dm)	45.9	22.3	76.9	56.5	22.6	103.4
Rain days	Days	57.0	30.0	88.0	62.00	30.0	88.0
Mean temperatures	Degrees Celsius	28.1	18.0	38.0	25.1	20.0	32.0
Area under maize	Hectares	28,987.8	9,300.0	44,800	78,794.7	45,000.0	147,350.0
Maize producer price	Kenya shillings/kg	24.9	8.0	55.0	4.7	3.0	6.0
Maize production	Metric tonnes	43,219.7	1,946.0	64,890.0	55778.6	11,251.0	96401.0
Real beef prices	Kenya shillings/kg	4.3	1.8	7.5	4.3	1.8	7.5
Stocking rate	Tropical livestock unit	-	-	-	4.7	2.9	6.5
Labour	Human population	326,399.3	40,500.0	59,8365.0	677,110.8	446.430.0	919,024
Livestock offtake/ha	Tropical livestock unit	6.2	3.2	12.7	5.6	2.4	9.6
Livestock offtake	Per cent	5.6	2.4	9.6	18.526	4.1	31.3

Source of Data: Ministry of Agriculture; County Annual Reports; National Statistical Office; National Meteorology Departments; FAOSTAT (2010); KIPPRA (2010).

8.6.2.1 Ordinary Least Squares Model (OLS)

Table 8.4 shows that out of the ten independent variables included in the analysis in each county, only one and three variables were significant at p≤0.05 for Kajiado and Makueni Counties respectively. In Kajiado County, per cent livestock offtake was significant at p≤0.05 and showed a positive relationship with income per adult equivalent. This outcome implies that an increase in per cent livestock offtake increases the total income. Other variables that were significant but at p≤0.10 for Kajiado County were maize price per kg and mean annual temperature. Maize price per kg showed a positive relationship while mean annual temperature had a negative response to income per adult equivalent.

Table 8.4: Results of OLS for Kajiado and Makueni Counties

Variables	Kajiado		Makueni	
	Coefficients	t-value	Coefficients	t-value
Constant	-	-1.679		-2.955**
Maize price per kg	0.190	1.893*	0.137	1.207
Rain days/per year	0.022	0.352	0.093	1.549
Mean annual temperatures	-0.120	-2.006**	- 0.004	- 0.076
Area under maize cultivation	0.084	1.242	0.041	0.591
Maize production (metric tonnes)	0.035	0.516	-0.052	-0.675
Beef prices/kg	-0.104	-0.577	0.392	2.552**
Lags annual rainfall (mm)	0.065	0.909	-0.023	-0.453
Drought	-0.094	-1.251	-0.044	-0.750
Labour (human population)	0.138	0.954	-	-
Per cent livestock offtake	0.808	4.459**	-	-
Livestock offtake/ha	-	-	0.713	5.504**
Stocking rate	-	-	0.306	3.271**

****Significant at $p<0.05$, *Significant at $p<0.10$**
Kajiado: Adjusted R^2 = 0.955, F = 40.184, Durbin Watson (*d*) =1.524 ($p\leq0.05$)
Makueni: Adjusted R^2 = 0.954, F = 60.769, Durbin Watson (*d*) =1.475 ($p\leq0.05$)

In terms of the overall model, the R^2 values of 0.955 in Kajiado County and 0.985 in Makueni County were too high, implying that only three variables explain the huge variation in the total income per adult equivalent in Kajiado and Makueni Counties. Besides, the values of Durbin Watson (*d*) were 1.524 and 1.475 for Kajiado and Makueni Counties respectively. According to Gujarati (2003), d is approximately equal to $2(1-r)$, where r is the sample autocorrelation of the residuals, $d = 2$ indicate no autocorrelation. If the Durbin-Watson statistic is less than 2, then the conclusion is that there is a positive serial correlation. These results confirm the problem of positive serial autocorrelation in the OLS model; therefore OLS was not a better-fit model for the data. The correlation matrix for variables used in OLS regression for Kajiado and Makueni Counties are shown in Annex 4 and Annex 5 respectively.

8.6.2.2 Results of Autoregressive (AR) Model

In the autoregressive model, only two variables in each county were significant at $p \leq 0.05$ (Table 8.5). In terms of the overall AR model, the R^2 values of 0.935 in Kajiado County and 0.970 in Makueni County appeared too high. According to Gujarati (2003), if the t-value (tau statistics) is less than the Durbin h critical value, we fail to reject the null hypothesis. The results confirm the problem of autocorrelation in the data. Therefore, the AR model is not an appropriate model. The correlation matrix for variables used in AR model for Kajiado and Makueni Counties are shown in Annex 6 and Annex 7 respectively.

Table 8.5: Results of Autoregressive (AR) model

	Kajiado		Makueni	
Independent Variables	Coefficients	t-value	Coefficients	t-value
Constant	-	-1.415	-	-2.470**
Drought years (yes or no)	-0.141	-1.747*	0-.042	-0.704
Number of rain days/year	0.053	0.708	0.085	1.361
Annual mean temperature	-0.121	-1.647	-0.018	-0.302
Maize production (metric tonnes)	0.146	1.820*	-0.051	-0.651
Lagged income /AE	0.137	0.973	0.088	0.618
Maize prices/kg	0.255	2.308**	0.146	1.252
Per cent livestock offtake	0.602	2.790**	-	-
Beef prices	0.220	1.013	0.345	1.985**
Lagged annual rainfall	0.082	0.970	-0.032	-0.608
Human population	- 0.174	-0.962		-
Area under maize	-	-	0.030	0.457
Stocking rate	-	-	0.304	3.198**
Livestock offtake/ha	-	-	0.673	4.592**

****Significant at $p<0.05$, *Significant at $p<0.10$**
Kajiado: $R^2 = 0.935$, $F = 27.545$ ($p \leq 0.05$), H-Value = 37.97
Makueni: $R^2 = 0.970$, $F = 53.48$ ($p \leq 0.05$), H-Value = 36.41

8.6.2.3 Results of Generalised Least Square Model (GLS)

The outcome of the GLS Model is shown in Table 8.6. The GLS analysis shows that four variables (first order lag total annual rainfall, maize price per kg, mean annual temperature and per cent livestock offtake) and three variables (beef price per kg, livestock offtake per ha and stocking rate) were significant at $p \leq 0.05$ in Kajiado and Makueni Counties respectively. In both the OLS and AR, the numbers of the significant variables were fewer and the R^2 values were too high to be explained by the few variables that were significant at $p \leq 0.05$. Therefore, this leaves the GLS model as the most appropriate in the present case, and it was adopted for the discussion. The correlation matrix for variables used in GLS regression for Kajiado and Makueni Counties are shown in Annex 8 and Annex 9 respectively.

Lagged total annual rainfall had a positive and significant influence ($p \leq 0.05$) on total income in Kajiado County. This implies that an increase in rainfall increases the income per adult equivalent. This may be possible for pastoral households that grow maize along the river valleys. Higher rainfall would mean greater maize production thereby increasing total income. Generally, more rainfall implies more pastures for the livestock. Hence pastoralists may be unwilling to dispose of animals, leading to reduced total income. Thus, in as far as livestock production in pastoral system is concerned; this may as well be as unexpected result.

Table 8.6: Results of GLS for Kajiado and Makueni Counties

	Kajiado		Makueni	
Variables	Coefficients	t-value	Coefficients	t-value
Constant	-	0.326	-	0.882
Human population	-0.121	-0.927	-0.090	-0.787
Drought	0.202	1.346	-0.243	-1.709
Lagged total annual rainfall	0.519	3.556**	-0.227	-1.968**
Maize price per kg	0.390	3.101**	0.163	1.432
Beef prices per kg	0.130	0.834	0.241	2.201**
Mean annual temperature	-0.441	-3.698**	-	-
Maize production(metric tonnes)	0.228	1.732	-	-
Per cent livestock offtake	0.660	4.707**	0.580	4.978**
Rainfall days per year	0.229	1.818*	0.228	1.885*
Stocking rate	-	-	0.461	4.400**

**** Significant at $p \leq 0.05$, * Significant at $p \leq 0.10$**
Kajiado: $R^2 = 0.801$, F-Value = 8.516 ($p \leq 0.05$), Durbin Watson (*d*) = 2.098
Makueni: $R^2 = 0.813$; F-Value = 10.886 ($p \leq 0.05$), Durbin Watson (*d*) = 1.9991

In Makueni County, lagged rainfall had a negative and significant ($p \leq 0.05$) influence on total income. It implies that an increase in rainfall amounts leads to a decrease in total income. The negative effect may occur if the rains are too high to cause floods, resulting in reduced crop production and pasture growth. Some parts of Makueni County are prone to flooding and this may explain the negative effects of the total rainfall. Alternatively, since total income is from various sources, including remittances, the flows from other sources might be reduced during times of high rains due to expectations of adequate harvests.

In contrast, Tasokwa (2011) found a negative influence between rainfall and maize production in Malawi. She reported that a decrease in rainfall due to droughts results in a decrease in maize production. Also, Raddatz (2005) acknowledges the importance of rainfall shocks on the growth of agricultural output. His work reveals the importance of weather shocks especially droughts, extreme temperatures and windstorms to the overall growth performance in low income countries like Nigeria. Further, Sissoko *et al*. (2011) established that in Ghana annual rainfall levels and their temporal distribution have a far-reaching impact not only on water availability and quality but also on crop yields, consequently influencing food security at household and national levels.

Other variables that were significant at $p \leq 0.05$ in Kajiado County were maize price per kg, mean annual temperature and per cent livestock offtake. Maize price has a positive response to total income. The result shows that an increase in maize price increases total income. It is understood that with higher maize prices, less food will be purchased with the available income. However, the households that grow maize along the river valleys or through irrigation normally have higher incomes due to higher maize producer prices. Similarly, for these households that grow maize, higher maize prices imply more income to purchase extra livestock, which increases their capital base.

The mean annual temperature exhibited a negative and significant ($p \leq 0.05$) relationship with income per adult equivalent in Kajiado County. Since the county is mainly involved in livestock production, this implies that an increase in temperature will negatively affect the production of livestock, which will in turn lead to a decrease in total income. In support, Frank *et al.* (nd) showed that an increase in air temperature markedly reduces milk production levels in the central Great Plains of the United States unless counter-acting measures were taken by producers. He further elaborated that increased ambient temperatures led to depressed voluntary feed intake, thus reducing livestock output.

According to Osbahr and Viner (2006), the annual average temperature in Kenya is projected to increase by between 3^0C to 5^0C by the end of the millennium because of climate variability and change. The increase in temperature brings consequences such as loss of moisture and increased evaporation rate. Coupled with declining precipitation, climate variability and change worsen the aridity of pastoral rangelands and affect a number of resources such as water, pasture and the edible fruits that pastoralists depend on. The ensuing consequences would be the decimation of livestock in large numbers, which could significantly affect pastoral livelihoods and security (Savatia, 2009). This implies that the Kajiado County population is threatened by food security if appropriate technologies and policies are not formulated.

The results of the current study are consistent with those of similar studies in other agricultural systems. For example, Tasokwa (2011) established that higher temperatures lower maize production. She further explained that in areas exposed to higher temperatures such as Chikhawawa, which have average temperatures of 32.48^0C, maize production was slightly lower than in Ntcheu that has mean temperatures of 30.52^0C. Also, Battisti and Naylor (2009) showed that an increase in temperature in the tropics may reduce maize and rice yields by 20 to 40 per cent at the end of this century. Likewise, Schlenker and Roberts (2006) showed that in North-eastern US, an increase in temperature beyond a threshold of 30^0C will result in sharp reduction of maize yields.

In lower altitudes, IPCC (2007) projects reduced crop productivity for even relatively small local temperature increases of 1 to 2^0C. In addition, IPCC projects that in the tropics and subtropics, crop yields may fall by 10 to 20 per cent by the year 2050 due to warming and drying, but there are places where yield losses may be much more severe (Jones and Thornton, 2003; Thornton *et al.*, 2007).

Stocking rate had a positive and significant influence ($p \leq 0.05$) on total income in Makueni County. Nyariki (2008) noted that correct stocking rate ensures correct intensity of utilisation of available forage, water and other resources, and is therefore an indicator of capital investment and management quality. He further stated that if the stocking rates were too high, they would lead to overgrazing and possible range degradation. The positive effect of the stock rate on total income in the model indicates that there is a mismatch between livestock and the available forage. This implies that if stocking rates were to be increased, livestock production would increase and total income would also go up. In addition, Makueni County being an agricultural community, the crop residues at the end of every growing season complement natural pastures. This result is similar to those of previous studies such as Nyariki (2008).

The other variables used in the model but were insignificant for both counties are drought and human population. The possible reason for the insignificance of human population could be that the population at county level may not necessarily reflect the actual labour for livestock offtake and output per unit land area for both Kajiado and Makueni Counties. In most studies, it is noted that an increase in human population results in land fragmentation, soil infertility due to over-cultivation and scramble for resources which may lead to reduced production per unit of land. On the same note, drought was found to be insignificant at $p \leq 0.05$. The probable reason could be that drought has become more frequent and occurs on annual basis, therefore there were no interannual variations.

8.7 CONCLUSION AND RECOMMENDATIONS

The results have shown that total income is influenced by climate variability (rainfall and temperature) in Kajiado and Makueni Counties of Kenya. GLS model was selected as the most appropriate among the estimated models to determine the causes of vulnerability to food insecurity in the study area. Both rainfall amounts and distribution are important factors when establishing the impact of different variables on total income. The assessment of impacts and vulnerability to climate variability and change requires localised data so that adaptation strategies can address the specific challenges in the area. Therefore, those involved in policy interventions should ensure that relevant climate data are collected and recorded for each specific area so that forecasting can be more accurate and can provide better guidance for designing appropriate adaptation strategies. Besides, climate factors are highly variable and thus strategies for adaptation cannot be generalised and should therefore be site specific. Initiatives that promote the creation of micro-climates such as agroforestry should therefore be encouraged and supported. This will help in moderating temperatures as well as attracting rainfall, while also offering other benefits, especially multipurpose trees and shrubs are emphasised.

Livestock also has played and will continue playing an important role in pastoral and agropastoral communities in Kenya. Per cent livestock offtake had a significant contribution to the total income. In Kajiado County, livestock contributed 78.2 per cent of the county total income while in Makueni County it accounted for 38.2 per cent. Therefore, efforts to help communities' access ready livestock markets at appropriate prices in a timely manner would help reduce income fluctuations. Relevant markets can therefore be made available and the government, on behalf of the communities, can negotiate the price in advance. This would shield farmers from inflation and exploitation by market cartels.

GLS shows that per cent livestock offtake remains an important parameter for the livelihoods in both Kajiado and Makueni Counties. It had a positive and significant influence on total income for both counties. Therefore livestock plays an important role in the total income of communities in the two counties. Therefore, development interventions geared towards livestock improvement have greater potentials to improve total income. For example, decentralisation of bodies such as the Kenya Meat Commission, milk processing plants and leather industries to county level are fundamental. This will help minimise exploitation of farmers by middlemen. In addition, strengthening of extension services, provision of mobile veterinary care clinics, and improving education and awareness among the transhumant pastoralists and agropastoralists should be prioritised. Besides, relying on livestock sales alone may be unsustainable. There is therefore the need to create micro-industries that deal with the processing of livestock related products such as hides and skins to improve household income as well as create non-farm employment.

Also, development initiatives that would specifically target Kajiado County should include implementing agroforestry and reforestation programmes to help ameliorate the high temperatures and attract more rainfall. Also, for households that are already practising cultivation, inputs such as fertilizers could be made affordable to increase their production. In addition, extensions services on better crop and animal husbandry will help improve farm management.

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CHAPTER NINE

GENERAL CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

9.1 GENERAL CONCLUSIONS

This study has generally shown that the climate of the study area has been varying from time to time. This variation has also been imposing challenges related to food insecurity, poverty and overall development of the Southern Rangelands of Kenya.

Climate variability and change impacts in Kenya have the potential to undermine national efforts targeted on poverty, food insecurity reduction and the achievement of millennium development goals. Because of the combination of anthropogenic and natural factors, the problem of food insecurity has been getting worse in many parts of the country. Semi-arid and arid regions of Kenya such as Kajiado and Makueni Counties are highly vulnerable to climate variability and change, and consequently to food insecurity. Agriculture and pastoralism are major livelihoods in these counties. These livelihoods are directly or indirectly dependent on natural resources; therefore climate variability and change matters a lot. Rainfall and temperature trends have confirmed that there is climate variability in the study area. Local community perceptions together with climate data have also confirmed the changes in rainfall amount, distribution, rain days and timing. The local community believes that the amount of rainfall has been decreasing in the last few decades, attributed to environmental degradation and loss of vegetation.

Climate variability and change act as a multiplier in the threat to food security in the ASALs of Kenya. Climate variability and change affect all four dimensions of food security, viz. food availability, access, utilization and stability. Their impacts on food availability may be felt through changes in herd sizes, household sizes, rainfall amounts, rainfall days, mean annual temperatures and prices of agricultural products. These variables determine the production and productivity of livestock and crops.

9.2 GENERAL RECOMMENDATIONS

This study has demonstrated that food security has been significantly affected by climate variability and change in the study area. A number of recommendations have been suggested. These are outlined below.

1. **The need for institutional partnerships and collaboration to collectively combat impacts of climate variability and change on food security:** These collaborations ensure teamwork, including information and knowledge exchange and sharing, proper coordination and harmonisation, and efficient utilisation of resources. All stakeholders should be given equal opportunity to contribute to addressing the impacts of climate variability and change.

2. **Livelihood diversification:** The livelihood of the local community is entirely dependent on the natural resource base, which in turn depends on climate parameters such as rainfall and temperature. Once the amount of rainfall and levels of temperature vary, livelihoods are affected. Diversifying livelihood options is important to generate income and produce food from different sources and to withstand the shocks induced by climate variability and change.

3. **Establishing a database and information management system:** This system will help in the generation of baseline data to help monitor biophysical and socio-economic dynamics to support informed environmental decisions and planning.

4. **Promoting disaster risk reduction and early warning system:** The most common hazards in the study area are drought, flood and conflict. The local community has prioritized drought as the worst hazard. Local government institutions in collaboration with the local community should develop local early warning systems. All relevant stakeholders should integrate disaster risk reduction into their development endeavours and day-to-day activities.

5. **Building and strengthening of existing local knowledge:** The community is better informed about climate related problems. Hence, any system targeted to reduce the problem should put into consideration local knowledge. Moreover, local culture should take into consideration local technical knowledge

9.3 FUTURE RESEARCH

Given the findings of this study, future research should focus on the following:

1. Evaluate the impacts of extreme climate events and their associated adaptation options under different land-use systems in terms of technical feasibility, economic viability and environmental sustainability.
2. Test and evaluate the efficiencies of the climate forecasting methods in the drylands.

ANNEX 1: QUESTIONNAIRE ON CLIMATE VARIABILITY, LAND USE AND LIVELIHOOD SECURITY IN SOUTHERN RANGELANDS

A. Location/ Village/Community ……………………………………………………………

B. Questionnaire No……………………………………………………………………………....

C. Name of Enumerator: ....

D. Household number: ....Tribe...Date……………………

1. Household Information

1.1. Name of the respondent ....

1.2. Gender of the respondent: 0) Male 1) Female ....

1.3. Age of the respondent in years ....

1.4. Numbers of household members ....0) 0-5years ....1) 5-9 years ....
2) 9-14 years ....3) 15 years and above ....

1.5. Numbers of formal years of schooling by respondent ....

1.6. Number years lived by the respondent in the area? ....

1.7. What is your household's **main** source of income

0) Pastoral ....) Agropastoral ....2) Pure farmers ....3) Tourism ....4) formal employment…..5) Other (specify)

1.8 Estimate the total income per month for your household ....

2. Land-use and Land Tenure

2.1. In your opinion, has there been change in your land-use activities? 0) No 1) Yes

2.1.1. If yes, explain how your land-use activities have changed over time ....………………………………………………………………………………..

……………………………………………………………………………………………….....

2.1.2. If No, explain ...……………………………………………………………….................

2.2. What factors influence your choice of land-use practices below.

2.2.1. Crops grown……………………………………………………………………..........

2.2.2. Species of livestock kept …………………………………………………………..........

2.2.3. Others (specify) ……………………………………………………………….........

2.3.1 What was the average land size for your household in the following past years (depends on the age of household head).

a) 20 years ago ....b) 10 years ago c) 5 years ago................. d) last year...................

10 years ....

2.3.2. What is the current average land size for your household?

………………………………………………………………...

2.3.3 In case of change in land size, what are likely causes of change in the land sizes?

………………………………………………………………...

………………………………………………………………...

2.3.4. How has change in land size affected your land-use practices?

………………………………………………………………………………………………..

……………………………………………………………………………………………......

2.3.5. How do you currently cope with changes in land size in managing livestock?……………………………………………………………………........…………

………………………………………………………………………………………..................

2.3.6. Do you have institutions regulating your land-use practises?

………………………………………………………………………………………………..

2.3.6.1. If yes, what is the role of each institution?

…………………………………………………………………………………………….....

2.3.6.2. If no explain ………………………………………………………………….............

2.4. What is the land tenure system practiced by your household?

Individual 1) communal 2) corporate (company) 3) others (specify)

3. Animal Production

3.1 Do you keep animals? 0) No ....1) Yes ....

3.2 Which type of animals do you keep? Indicate the number animals you own.

1) Cattle ....2) Sheep ....3) Goats ....4) Donkeys ....5) Others ....

3.3 Have you experienced change in number of livestock owned in the past one year?

0) No ....b) Yes ....

Explain ....

3.4. How many animals were born in your household in the last six months?

0) Cattle ....1) Sheep ....2) Goats ....3) Donkeys ....4) Others ....

3.5.1. How many animals died in your household in the last six months?

0) Cattle............1) Sheep.............2) Goats.............3) Donkeys...........4) Others.............

3.5.2. Please specify the cause of death ....

3.5.3. Indicate the number of animal sold by your household the last six months?

0) Cattle ....1) Sheep ....2) Goats ....3) Donkeys ....4) Others ....

3.5.4. What was the price per animal in Kshs?

0) Cattle ....1) Sheep ....2) Goats ....3) Donkeys ....4) Others ....

3.6. What period of the year do you normally sell your animals ....

....

Explain ....

3.7. Rank the possible reasons for selling your animals in order of importance over the last six months?

a) Drought

b) School fees

c) Buy food

d) Others (specify)

3.8. What are the problems you encounter in selling your animals?

…………………………………………………………………………………………………

………………………………………………………………

3.9. Milk production

2.9.1 How many cows were in milk in the last six months …................................

2.9.2 What was the average daily milk yield per cow per day …........... (in litres)

2.9.3 How much of the daily production was i) consumed ….......litres

ii) sold ....Price per litre ….................Total sales (in kshs) ....

3. Agricultural Production

3.1.1 Has your household been involved in farming during the last six months? 0) No 1) Yes

3.1.2 If No, explain 1) Drought 2) seed unavailability 3) other reasons (specify)

3.1.3. If yes, indicate main cereal crops cultivated

0) Maize ....acres ....1) Others (specify) ....acres

3.1.4. What was the harvest per crop…………………

0) Maize ....

1) Others (specify) ....

3.2.1 Indicate the main legumes cultivated: 0) Beans acres 1) others (specify) ....acres

3.2.2. Acreage under cultivation …………..........................No of bags harvested ………………

3.3. Indicate main fruit crops cultivated ....

3.4 For crops sold, mention the total amount sold during the last six months and the price per unit. Crops ………..Amount sold …............(in Kgs) ....Price per unit (kshs) ..……

3.5.1 Have any pests / diseases affected any crops under cultivation or in storage during the last six months? ....1) Yes ....0) No ....

3.5.2. If yes, provide details ....

4. Knowledge on climate situations and sources of climate information

4.1. Do you think weather has changed in this area? 0) No 1) Yes……..

If yes, give reasons ………………………………………………...........................

....

4.2. How have these changes affected your household? (Probe for positive and negative effects)

4.2.1. Negative effects …………………………………………………………………

…………………………………………………………………………………………

4.2.2. Positive effects ……………………………………………………………...............

……………………………………………………………………………………………..

4.3. Which of the following climate related disasters have you experienced in the past 10 years? (Record frequency, risks and the trends in the table below)

Extreme weather event	Frequency	Risks	Trend
Drought			
Floods			
Hailstorms			
Landslide			
Afflotoxin			
Diseases and pests			
Others (Specify)			

Frequency: 0 = not at all 1= every year, 2= 2.3 years, 3= 3-5 years 4= 5-7 years, 5= every 10 years or more

Risks: 0 = no risk, 1= low risk, 2 = medium risk and 3 = high risk

Trend: 0 = decreasing, 1= constant, 2= increasing 3 = others (specify)

4.5.Do you receive any climatic information? 0) No………1) Yes

4.6.What type of information do you receive? From where and how often and who receives it? (For each type of information, indicate the source and how the information is received)

Type of climate information received	Source	Information recipient

4.7. Is the climate information received useful in planning your land use activities?

0) No .... 1) Yes ....

a) If Yes, explain how?

…………………………………………………………………………………………………

…………………………………………………………………………………………………b

b) If no, why? ……………………………………………………………………………...

4.8. What would like improved on the current weather information received and why?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

5. Other Economic Activities

5.1. How many members of your family were actually engaged in casual labour in the last six months? 1) Yes, how many?................Total income (kshs) …………………0) No, why ……………………………………………………………………………………….........

....

5.2. Did your household receive any remittances or gifts in the last six months? 0) No 1) Yes,

If yes, from whom …………………………. and what was the value in Kshs ....

5.3. Are any of your household members employed? 0) No ....1) Yes ....

If yes, give details in the table below. If no, go to question 5.

Type of employment	Monthly income	Usage	Comment

5.4.Do you participate in any other economic activity? No ....1) Yes ....

If Yes, Specify the activity and the income earned on monthly basis

Type of employment	Monthly income	Usage	Comment

6. Food Purchases

6.1. Cereal/ legume purchases

6.2. Did your household buy cereals / legumes in the last six months? Yes ..../ No ....

6.3. What were the quantity purchased and the price per kilogram (pp/kg)?

a) Whole maize: 1) Yes 0) No Qty ....(pp/kg)

b) Posho (locally milled): 1) Yes 0) No ....Qty ....(pp/kg)

c) Beans ....1) Yes ....0). No Qty ....(pp/kg)

d) Rice ....1) Yes 0. No …………. Qty …………(pp/kg)

e) Sugar ……………………1) Yes ……….0. No ………Qty ……… (pp/kg)

f) Fats and oils ....1) Yes 0). No Qty ....(pp/kg)

g) Milk ....1) Yes 0). No Qty ....(pp/kg)

h) Meat ....1) Yes 0). No Qty ....(pp/kg)

i) Others (specify) ....1) Yes 0). No Qty ....(pp/kg)

7. Other Significant Income Generating Activities

7.1. Did your household members get involved in any other income generating activities apart from your main source of livelihood and casual labour in the last six months? 0) No 1) Yes......(specify and the amount earned)..

7.2. How many members of the household were involved in the above activities ....

7.3. Have you ever obtained any credit facilities in the last six months?

a) Government ....

b) Relatives and Friends ....

c) Non- governmental organisations ....

d) Others (specify) ....

7.4. What form was the credit? 0) kind .... (kshs) ....1) cash value (kshs) ....

6.5 Do you have any member of your household employed elsewhere? 1) Yes 0) No

If yes, is the employment 1) permanent 0) temporary: give details on his/her place of work ……………………….type of employment ....

Age …………………gender …………….year he started the work …………........................

7. Welfare

7.1 Did your household receive any aid during the last six months? 1. Yes ....0) No ....

(If No go to questions17.0)

7.2 Mention the type of aid received in the last six months ....

(Relief food/ food for work/ cash for work/others) value (kshs) ....

7.3 Mention the quantity of food aid your house hold received in kilogram during the last six months ....

a) Number of Kgs relief food (cereals) per household: ....

b) No of Kgs from FFWs (cereals) per household ....

c) Others (specify) ……………………………………………………………………….......

8. Climate Information

8.1. In your opinion, has weather of this area changed over the years?.0) No ….. I) Yes …….

8.2. What are the climate related disasters that have occurred in the over the last years below.

a) 20 years? ....

b) 10 years ……………………………………………………………………………….

c) 5 years ………………………………………………………………………………….

8.3. In the years stated in 8.2 above, which of this listed climate extreme event was the most frequent)

a) 20 years? ....

b) 10 years ………………………………………………………………………

c) 5 years ………………………………………………………………………

8.3.2. How did you respond to this extreme climate event?..

8.4. From what source do you get weather related information?

8.5. Do you trust the source of information in predicting the future weather? a) Yes ...b) No ……. (Explain) ……………………………………………………………………………..

8.6. How does the information help you in planning your land-use activities? ……………

8.7. What would you do if the weather forecast showed that there would be no rain next season?

8.8. What would you do if the weather forecast showed that there would be continuous drought for the next one month? ……………….

8.9. In your opinion, how can the weather information be improved to be very useful to you? ……………………

8.10. If the climate has been varied; what strategies have you used to adapt to climate variability? ……….

8.11. Was there any observable indicators suggesting there would be changes in weather in that year? 1) Yes ………0) No…….. if Yes, what were they? ....
....

END OF QUESTIONNAIRE

THANK YOU FOR YOUR PARTICPATION

ANNEX 2: FOCUS GROUP DISCUSSION

1. Location/division/district
2. Have you ever noticed changes in climate variation?
3. What changes in the environment can you associate with climate variation?
4. Can you remember when some of these changes took place?

Meteorological Information

1. Is there much variability in the timing/quantity of rainfall each year? Do you have data available on annual rainfall (at least for the last 20 years)?
2. Are there local weather forecasts/climate information available? How is the information distributed now?
3. What are the plans for the future? What additional information would be helpful?

Farmers

1. What are the typical crops in this area?
2. Are crops mostly for local consumption?
3. What is the typical land tenure structure in this area?
4. How do farmers decide what and when to plant?
5. How easy is it for farmers to obtain credit?
6. Do many farmers have other sources of income besides their crops? Could you provide examples?
7. What are the major vulnerabilities of farmers in this area? For rain fed agriculture? For irrigated?
8. Are there particular strategies that help mitigate these vulnerabilities?
9. Are there particular subpopulations of farmers that are most at risk? Why is that?
10. What were the dry periods over the past 20 years? Can you think of any particularly bad year for farmers?
11. How did individual farmers prepare for the drought?
12. Were crop losses widespread?
13. How do people compensate for crop losses? What did they do in 19xx/20xx?
14. The percentage of people in agriculture has dropped significantly over the past 20 years. Is there a future for agriculture in this area?

Pastoralists

1. What are the typical animals in this area?
2. Are crops mostly for local consumption?
3. What is the typical land tenure structure in this area?
4. How do pastoralists decide on what type of animal to keep, when to sell and where to graze?
5. Where do you graze your animals in the dry and wet seasons (give reasons)?
6. How do you relate the grazing patterns of different animal/ class to forage and water availability?
7. What is your grazing / topology calendar showing grazing movements across the year?
8. Are there any traditional (or other) controls to regulate grazing patterns? If yes, do they vary with season (wet, dry) years?
9. How easy is it for pastoralists to obtain credit?
10. Do many pastoralists have other sources of income besides their livestock? Could you provide examples?
11. What are the major vulnerabilities of pastoralists in this area?
12. Are there particular strategies that help mitigate these vulnerabilities?
13. Are there particular sub-populations of pastoralists that are most at risk? Why is that?
14. What were the dry periods over the past 20 years? Can you think of any particularly bad year for pastoralists?
15. How did individual pastoralists prepare for the drought?
16. Were livestock losses widespread?
17. How do people compensate for livestock losses? What did they do in these particular years (19xx/20xx/…)?
18. The percentage of people practising pastoralism has dropped significantly over the past 20 years.
19. Is there a future for pastoralism in this area?

Drought Response

20. Are drought (and fire) major political concerns in this area?
21. Is there government assistance available in the case of a drought?
22. Given that droughts in this region are common, what measures are in place to assist those affected?
23. Are there any government efforts to reduce vulnerability of farmers?

24. Are there other government programs to assist farmers/pastoralists?

25. What do you consider the most important factor for preventing widespread hunger in the case of crop/livestock losses?

26. What has changed in the response to drought over the past 20 years? What was the most dramatic change? What change most affected the vulnerability of farmers/ pastoralists (for better or worse)?

27. Are there preparations being made to respond to future impacts from climate change? Is the government thinking about this? Are farmers and or pastoralists thinking about this?

28. Is there anything I have not asked you about that you think is important for me to know about climate vulnerability in this area?

ANNEX 3: TRENDS IN VARIABLES USED IN THE TIME SERIES ANALYSIS (1980-2010)

	Kajiado					Makueni				
Year	Annual rainfall (cm)	Maize price/kg	offtake/ha	Beef prices/kg	Income per adult equivalent	Annual rainfall (cm)	Offtake/ha	Stocking rate	Beef prices/kg	income per adult equivalent
1980	3.51	8	2.4	1.8	552	4.11	2.4	6.5	1.8	828
1981	3.84	12	2.6	1.91	589	6.53	2.6	6.3	1.9	884
1982	4.68	13	3	1.98	694	9.38	3	5.9	2	1041
1983	3.47	18	3.2	2.2	600	2.59	3.2	5.7	2.2	900
1984	2.23	20	3	1.95	523	6.89	3	5.5	2	785
1985	3.51	23	2.4	1.8	678	5.02	2.4	5.3	1.8	1017
1986	3.84	18	2.6	1.91	717	5.67	2.6	5	1.9	1076
1987	4.68	23	3	1.98	795	3.07	3	4.9	2	1193
1988	3.21	18	5.4	3.6	834	5.45	5.4	4.8	3.6	1251
1989	3.76	21	4.6	3.8	965	10.34	4.6	5	3.8	1448
1990	3.16	20	4.8	3.9	876	7.78	4.8	5.2	3.9	1314
1991	7.25	15	4.3	4.1	710	4.83	4.3	5	4.1	14475
1992	4.33	25	5.1	4.3	1272	5.98	5.1	5.2	4.3	1314
1993	6.65	15	4.3	4.5	1134	4.58	4.3	6.3	4.5	1065
1994	7.61	20	3.9	4.5	1021	4.72	3.9	4.9	4.5	1908
1995	7.39	21	4.6	4.6	1299	3.77	4.6	4.9	4.6	1701
1996	4.58	27	6.1	4.6	1312	4.53	6.1	4.4	4.6	1531
1997	6.29	13	7.8	4.4	1355	8.05	7.8	4.3	4.4	1948
1998	7.12	15	5.2	4.5	1103	10.11	5.2	4.1	4.5	1968
1999	7.69	20	5.8	5.3	1086	7.35	5.8	4.1	5.3	2032
2000	2.59	23	6.2	5.5	984	5.21	6.2	4.2	5.5	1654
2001	3.01	30	6.5	5.5	1156	5.83	6.5	4	5.5	1629
2002	3.42	32	7	5.9	1293	4.88	7	4.2	5.9	1476
2003	3.87	35	7.5	6.1	1356	3.92	7.5	4	6.1	1734
2004	2.26	40	8.4	5.8	995	5.01	8.4	3.9	5.8	1939

2005	6.23	50	9	5.8	1389	2.26	9	3.9	5.8	2034
2006	5.07	45	9.6	5.6	1439	8.74	9.6	3.8	5.6	1492
2007	4.82	35	8.2	5.9	1477	4.68	8.2	3.6	5.9	2083
2008	4.46	35	8.5	6.3	1135	4.89	8.5	3.5	6.3	2158
2009	3.92	55	9.2	6.9	1343	4.62	9.2	3.2	6.9	2216
2010	3.81	27	8.7	7.5	1392	4.23	8.7	2.9	7.5	2091

Source of Data: Government of Kenya, District annual reports, KIPPRA (2010).

ANNEX 4: OLS CORRELATION MATRIX FOR KAJIADO COUNTY

Variable	Lag annual rainfall	Labour-Human population	Area under maize cultivation	Mean annual temperature	Rain days/year	Maize production	Drought dummy	Maize price/kg	Beef prices/kg	Per cent offtake
Lag annual rainfall	1.000									
Labour (human population)	0.094	1.000								
Area under maize	0.218	0.377	1.000							
Mean annual temperature	-0.261	0.222	0.164	1.000						
rainfall days/year	0.167	0.114	0.037	0.193	1.000					
Maize production	0.373	-0.488	-0.185	-0.405	0.027	1.000				
Drought Dummy	-0.510	0.002	-0.502	-0.003	-0.041	-0.212	1.000			
Maize price/ kg	0.167	-0.446	-0.400	-0.287	0.339	0.297	0.205	1.000		
Beef prices/kg	-0.234	-0.401	-0.330	-0.082	0.134	0.195	0.358	0.320	1.000	
Per cent offtake@	0.055	-0.176	0.113	-0.002	-0.270	0.047	-0.395	-0.322	-0.745	1.000

ANNEX 5: OLS CORRELATION MATRIX FOR MAKUENI COUNTY

Independent variables	Offtake/ha	Mean annual temperature	Lags annual rainfall	Drought dummy	Area under maize	Rain days/year	Maize production	Stocking rate	Maize prices	Human population	Beef prices
Offtake/ha	1.000										
Mean annual temperature	0.197	1.000									
Lag annual rainfall	0.474	0.253	1.000								
Drought years	-0.014	0.090	0.253	1.000							
Area under maize	0.368	-0.198	0.227	0.150	1.000						
Rain days/year	-0.088	0.049	-0.295	-0.555	-0.130	1.000					
Maize production	0.240	0.312	0.252	0.068	-0.116	-0.293	1.000				
Stocking rate	0.392	0.221	0.029	-0.254	0.012	0.295	-0.074	1.000			
Maize price/kg	-0.210	-0.535	-0.420	-0.524	0.069	0.478	-0.314	0.063	1.000		
Human population	0.204	0.261	0.077	-0.069	-0.017	0.125	0.341	0.556	-0.108	1.000	
Beef price/kg	-0.511	0.069	-0.112	0.237	-0.433	-0.184	-0.074	-0.363	-0.290	-0.672	1.000

ANNEX 6: AR CORRELATION MATRIX FOR KAJIADO COUNTY

	Lag offtake/ha	Mean temperature	Drought (dummy)	Maize production	rainfall days/year	Area under maize	Lag annual Rainfall	Maize price per kg	Beef prices/kg	Per cent offtake
Lag offtake/ha	1.000									
Mean annual temperature	0.401	1.000								
Drought (dummy)	-0.120	-0.051	1.000							
Maize production	-0.075	-0.348	-0.231	1.000						
Rain days/year	-0.066	0.132	-0.033	0.099	1.000					
Area under maize	-0.115	0.035	-0.522	0.007	0.002	1.000				
Lag annual rainfall	0.154	-0.201	-0.521	0.463	0.146	0.176	1.000			
Maize price / kg	-0.305	-0.311	0.254	0.120	0.437	-0.230	0.174	1.000		
Beef prices/kg	-0.363	-0.139	0.406	0026	0.208	-0.153	-0.254	0.264	1.000	
per cent offtake	-0.273	-0.075	-0.350	-0.023	-0.227	0.219	0.027	-0.333	-0.711	1.000

ANNEX 7: AR CORRELATION MATRIX MAKUENI COUNTY

Variable	Lag per cent offtake	Lag annual rainfall	Rain days/yr	Mean annual temperature	Drought (dummy)	Area under maize	Maize production	Stocking rate	Maize prices	Offtake/ ha	Beef prices
Lag per cent offtake	1.00										
Lag annual rainfall	-0.30	1.00									
Rain days/year	-0.21	-0.23	1.00								
Mean annual temperature	-0.36	0.33	0.09	1.00							
Drought (dummy)	0.05	0.23	-0.55	0.08	1.00						
Area under maize	-0.25	0.29	-0.07	-0.09	0.132	1.000					
Maize production	0.02	0.22	-0.36	0.22	0.098	-0.12	1.00				
Stocking rate	-0.03	-0.01	0.27	0.10	-0.261	0.03	-0.34	1.00			
Maize prices/kg	0.12	-0.43	0.46	-0.53	-0.525	0.04	-0.29	0.14	1.00		
Offtake/ha	-0.44	0.53	-.0.01	0.29	-0.023	0.44	0.16	0.32	-0.22	1.00	
Beef prices/kg	-0.44	0.06	-0.03	0.45	0.209	-0.41	0.19	0.03	-0.49	-0.22	1.00

ANNEX 8: GLS CORRELATION MATRIX KAJIADO COUNTY

Variable	Lags annual rainfall	per cent offtake	human population	Mean annual temperature	Rain days	Maize price/kg	Total maize production	Drought (Dummy)	Beef prices/kg
Lags annual rainfall	1.000								
Per cent offtake	-0.049	1.000							
Human population	-0.197	-0.018	1.000						
Mean annual temperature	-0.383	0.025	0.015	1.000					
Rain days	0.085	-0.333	0.299	0.050	1.000				
Maize price/kg	-0.078	0.194	0.311	-0.229	0.288	1.000			
Total maize production	0.467	-0.117	-0.264	-0.195	-0.049	-0.146	1.000		
Drought (Dummy)	0.464	0.020	0.341	-0.259	0.248	0.256	0.215	1.000	
Beef prices/kg	0.180	-0.499	0.273	-0.164	0.270	0.085	0.361	0.456	1.000

ANNEX 9: GLS CORRELATION MATRIX MAKUENI COUNTY

Variable	Lagged rainfall amounts	Beef price/kg	Rain days/year	Stocking rate	Maize prices/kg	Human population	Offtake/ha	Drought Dummy
Lagged rainfall amounts	1.000							
Beef price/kg	-0.097	1.000						
Rain days/year	-0.100	-0.042	1.000					
Stocking rate	-0.202	-0.159	0.188	1.000				
Maize prices/kg	0.049	-0.213	0.391	0.145	1.000			
Human population	0.157	-0.346	0.055	0.093	0.293	1.000		
Livestock Offtake/ha	0.285	-0.328	-0.081	0.076	0.008	0.185	1.000	-0.153
Drought dummy	0.353	0.068	-0.518	-0.318	-0.271	0.177	-0.153	1.000