CLIMATE VARIABILITY AND CHANGE ON VULNERABILITY AND ADAPTATION AMONG TURKANA PASTORALISTS IN NORTH-WESTERN KENYA

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A Thesis Submitted in Fulfilment of the Requirements of the Degree of Doctor of Philosophy in Range Management, Faculty of Agriculture, University of Nairobi

DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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DEDICATION

This thesis is dedicated to my parents and family especially my lovely wife Janet, and children Lisa, Lenny and Joy. You have been a great source of inspiration and your support has made me realize what God intended me to be. May the gracious Lord bless you and THANK YOU!

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ABBREVIATION AND ACRONYMS

AEZ	Agro-ecological Zones
ANOVA	Analysis of Variance
ASALs	Arid and Semi-Arid Lands
AU	Africa Union
AVHRR	Advanced Very High Resolution Radiometer
CAHW	Community based animal health workers
CBO	Community Based Organization
CIDP	County Integrated Development Plan
DDC	Drylands Development Centre
DITSL	German Institute for Tropical and Subtropical Agriculture, Germany
DPI	Drought Severity Index
ENSO	El Nin˜o-Southern Oscillation
EOS	Earth Observation System
FAO	Food and Agriculture Organization of the United Nations
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GHG	Greenhouse House Emissions
GoK	Government of Kenya
GTZ	German Agency for Technical Cooperation
HDRO	Human Development Report Office
HEA	Household Economy Approach
HIV/AIDS	Human immunodeficiency virus infection / acquired immunodeficiency syndrome
HLPE	High Level Panel of Experts on Food Security and Nutrition
HSNP	Hunger safety Net programme
HVI	Household vulnerability index
ICPAC	IGAD Climate Prediction and Application Centre
ILRI	International Livestock Research Institute
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter-tropical Convergence Zone
KES	Kenya Shillings

KHBS	Kenya Household Budget Survey
KMS	Kenya Meteorological Services
KNBS	Kenya National Bureau of Statistics
LARMAT	Department of Land Resources Management and Agricultural Technology
LGP	Length of the Growing Period
MK	Mann-Kendall
MNL	Multi-Nomial Logit
MODIS	Moderate Resolution Imaging Spectro-radiometer
MTP	Medium Term Plan
NDMA	National Drought Management Authority
NDVI	Normalized Difference Vegetation Index
NGOs	Non-Governmental Organizations
NOAA	National Oceanic and Atmospheric Administration
OLS	Ordinary least squares
PCA	Principal Component Analysis
SPI	Standardized precipitation index
SPOT	Satellite Pour l'Observation de la Terre
TLU	Tropical Livestock Unit
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations International Strategy for Disaster Reduction
UN-OCHA	United Nations Office for the Coordination of Humanitarian Affairs
USAID	United States Agency for International Development
WFP	World Food Programme
WRI	World Resources Institute
WWF	World Wide Fund for Nature

DEFINITION OF KEY TERMS

The definitions of some concept and terms (such as resilience, vulnerability, and adaptation etc.), are increasingly becoming more important within the global change research community; though they do have diverse and somewhat separate definitions depending on context. In this study, broad definitions of commonly used terms in the thesis are provided along with alternative definitions where applicable (Adger 2006; Intergovernmental Panel on Climate Change IPCC 2001; 2007; 2012; 2014) as follows:

Adaptation: In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate.

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

Adaptive strategies are longer-term (beyond a single season) strategies that allow people to respond to a new set of evolving conditions (biophysical, social and economic) that they have not previously experienced. The extent to which communities are able to respond successfully to a new set of circumstances will depend upon their adaptive capacity.

Climate change: A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forces, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, and others) of the climate at all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

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

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

Extreme events comprise a facet of climate variability under stable or changing climate conditions. They are defined as the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends ('tails') of the range of observed values of the variable.

Mitigation refers to the elimination or reduction of the frequency, magnitude, or severity of exposure to environmental, economic, legal, or social risks, or minimization of the potential impact of a threat or warning.

Rangeland is defined by Society for Range Management as the "land on which the native vegetation, predominantly grasses, grass-like plants, forbs, or shrubs are suitable for grazing or browsing use". If plants are introduced, they are managed similarly. Rangeland includes natural grasslands, savannahs, shrub lands, most deserts, tundra's, alpine communities, coastal marshes and meadows. According to the World Resources Institute (WRI 2000), rangelands are extensive tracks of arid and semi-arid lands that are essentially unsuitable to rain fed cultivation, industrial forestry, protected forest, or urbanization.

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

Risk: This refers to the interaction of physically defined hazards with the properties of the exposed systems, such as 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.

Sensitivity: It is the measure of a system to be affected.

Vulnerability is defined as the propensity or predisposition to be adversely affected.

ABSTRACT

Climate variability and change is increasingly being recognized as a critical challenge to pastoral production systems in the arid and semi-arid rangelands. The projected climate scenarios are expected to aggravate some of the existing vulnerability of natural resource-dependent communities, and likely to impose new risks beyond the range of current experiences. An explicit understanding of households' vulnerability to climate variability and adaptation strategies is, therefore, crucial for targeting appropriate resilience interventions in pastoral environments. This study focused on better understanding of climate variability and change, in order to provide insights on pastoralists' risk management adaptations at a micro-level. In addition, the study investigated vegetation responses to precipitation anomalies in Turkana County of Kenya.

The research study used Mann-Kendall test statistics to investigate long-term rainfall (1950-2012) and temperature (1978-2012) changes. Household questionnaire survey, focus group discussion and key informants' interviews were used to collect primary data at household and community levels. A total of 302 households were sampled using multi-stage sampling technique, and information obtained analyzed using descriptive statistics and ordinal logistic regression model. In addition, Normalized Difference Vegetation Index (NDVI) data derived from Advance Very High Resolution Radiometer (AVHRR) satellite were overlaid with precipitation to generate vegetation maps. Analysis of variance (ANOVA) was used to analyse vegetation species richness and abundance in the study area.

The result revealed high inter-annual (coefficient of variation > 90%) rainfall variability, with seasonal uncertainty. There were more years with below normal rainfall than those with mean rainfall above long-term mean (LTM). Results indicate that extreme drought events have increased over the last 63 years, with 28.5% occurrences between 1950 and 1970, to 47.9% over the last two decades between 1990 and 2012. Further, the study revealed that the area is warming at 0.13°C, with a significant ($p<0.05$) rise in both minimum (0.2°C), maximum (0.1°C) temperature for the period 1979 - 2012. Pastoralists' perception of changes in climate characteristics matched the recorded data. As per the community perceptions, the effects of

climate variability and change are being felt by many households in Turkana. The vulnerability index analysis showed that majority of households were moderately (44%) to highly (27%) vulnerable to climate-induced stresses. Factor estimates of the probit model further revealed that the main determinants of pastoralists' vulnerability were sex of household head, number of dependents, marital status, social linkages, access to extension services and early warning information, herd structure and mobility, distance to markets, and access to affordable credit. The results highlight the need for interventions to empower women in the access to education, affordable credits, livelihood diversification opportunities, and to resources that can strengthen households' resilience to climate variability.

Vegetation will be key resources around which resilience to climate change and vulnerability will be build. In this study there was evidence that areas with low mean annual rainfall (< 200 mm/year) depicted stronger relationship between NDVI and rainfall compared to locations with mean annual rainfall of more than 300 mm/ year. Implying that NDVI may be more relevant in defining vegetation trends in arid zones compared to high more rainfall areas. In this study, there was enhanced vegetation greenness between 1998 and 2011. Only 30% of this change could be explained by rainfall anomalies, with the rest partly attributed to invasion of the rangelands by *Prosopis juliflora*. As perceived by various community groups the shifts of vegetation to more shrub bush-land will favor livestock diversification to browsers such as goats and camels. In general, the high rainfall variability and uncertainty was accompanied by raising temperature over the period under study. Besides climatic factors, socio-economic and bio-physical factors are crucial in determining households' vulnerability to climate variability and change dynamics. Thereforefore, interventions that are cognisant of changes anticipated, shift in vegetation composition, will require a holistic approach that not only focuses on drivers of climate variability and change, but also socio-economic factors central to building patoral resilience in arid environments.

CHAPTER ONE

INTRODUCTION

1.1 Background

There is widespread scientific consensus that the Africa continent is currently warmer than it was 100 years ago. The climate model-based predictions for the continent clearly suggest that this warming will continue and, in most scenarios, accelerate already existing vulnerabilities with significant impacts on natural and human systems (Hulme *et al.* 2001; Notenbaert *et al.* 2007; Nicholson 2014). Increasing temperature associated with climate variability and change will hit hardest rural communities - like those in sub-Saharan Africa - that already face social, political, economic and ecological challenges such as poverty, food insecurity or malnutrition. In fact, there is a growing concern that increasing climate variability and change will cause more harm to poor communities who rely more heavily on natural resources for survivals, have low adaptive capacity and are susceptible to droughts and flood episodes (Intergovernmental Panel on Climate Change IPCC 2012). This, in turn, is likely to impact negatively on livelihood systems and deepen communities' vulnerability to extreme climate change (Galvin *et al.* 2004). There is therefore the need for concerted efforts toward tackling this challenge.

Much of current literature on the science of climate acknowledge that the extreme weather events amplify vulnerability, intensify poverty, inequality and disrupt lives and livelihoods in many countries of sub-Saharan Africa (McCarthy *et al.* 2001). These are particularly true in low-income countries like Kenya where majority live in absolute poverty and are highly vulnerable to extreme climate shock and stresses (Herrero *et al.* 2010). Many developing countries, which have their economies largely depend on climate-sensitive agricultural production systems, are particularly at risk and vulnerable to the impact of climate change (Kempe 2009). However the extent of such vulnerability will depend on how efficiently communities adapt to the changing climatic conditions. According to Intergovernmental Panel on Climate Change - IPCC (2012) report, vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and adaptive capacity. This, implies, it is people's sensitivity and exposure to various variables of climate change as well as their adaptive capacity that determine whether they survive, and if they do, whether their production systems are destroyed. Often in the Horn of Africa, majority of households' are exposed to environmental and climate hazards such as droughts or floods, and with inadequate basic services or infrastructure to support adaptation options (Thornton *et al.* 2006). Studies show that majority of households in the arid and semi-arid regions have limited assets and scarce resources to use in adaption or coping with climate - induced shock or stresses (Ifejika 2010; Silvestri *et al.* 2012). Undoubtedly, extreme climate scenarios are likely to exacerbate vulnerability with much impact on human and natural systems in the arid and semi - arid regions unless effective adaptation and mitigation mechanisms are put in place.

Climate change is a long-term problem with multiple uncertainties. Existing literature on climate change attributes increase in temperature to emission of greenhouse gases (carbon dioxide, methane, nitrous oxide, hydro-fluorocarbons and others) produced by human activities (Hulme *et al.* 2001). Although the Earth's atmosphere contains numerous greenhouse gases, only carbon dioxide - CO_2 accounts for overwhelming majority of the greenhouse effect that leads to climate change. Anthropogenic emissions of carbon dioxide account for about 63% of the greenhouse gas warming effects in the long-term and for 91% in the short-term (Yvon-Durocher *et al.* 2014). However, despite the irresistible evidence on the causes of climate change, there is still ongoing debate not only on its causes but also over the amount of change and what the change is likely to entails. For Kenya, the reported 0.7°C - 2.0°C increase in temperature during the last 40 years, together with variable and unpredictable rainfall, has limited pasture growth, increased water scarcity and exacerbate rangeland degradation in many arid-and semi-arid lands - ASALs (Mutimba *et al.* 2010; Hoang *et al.* 2014). The predicted changes in annual maximum and minim temperatures in East Africa by the late-twenty first century are 1.8°C and 4.3°C, respectively (IPCC 2012). In ASALs, heavy rains, droughts and floods are becoming more frequent, particularly in northern regions of Kenya (Kirkbride and Grahn 2008; Osano *et al.* 2013; Nicholson 2014).

This study examines the influence of climate variability and change on pastoralists' vulnerability and adaptation in an arid environment of northern Kenya. Climate variability and change in-terms of erratic rainfall and its uneven sequential and spatial distribution create frequent drought and flooding. Previous studies (Kabubo-Mariara 2008; Ericksen *et al.* 2013) have revealed that high spatial and temporal fluctuations in rainfall and temperatures have implications on the pastoral production system which is one of the dominant economic activities in the arid and semi-arid zones of Kenya. That notwithstanding, pastoralism is seen to have immense potential for reducing poverty, generating economic growth, managing the environment, promoting sustainable development, and building climate resilience in arid and semi-arid ecosystems (African Union – AU 2010). Therefore, scientific investigations on pastoralists' vulnerability and adaptation to climate variability and change are critical for the management decisions in the ASALs.

1.2 Statement of the Problem

Climate variability and change has exposed pastoralists, their herds and ecosystem to risk associated with frequent droughts and flooding (Birch and Grahn 2007). During the recent 2008 - 2009 and 2010 - 2011 widespread droughts in the Horn of Africa, pastoralist lost approximately 60-70% of their livestock herd (Huho and Kosonei 2014), and about 3.2 million people were left in need of emergency assistance in arid and semi-arid regions of Kenya. For pastoralists, high livestock mortality has devastating effects on their lives and livelihoods. In fact, livestock is an integral form of pastoral capital, besides functioning as a means of production, storage, transport, transfer of food and wealth, and act as an insurance against weather risk such as drought (Behnke and Muthami 2011). Whilst pastoralists for a long has used indigenous ways of adapting to shock and stresses imposed by harsh environmental conditions, increasing frequency of extreme weather events is now bringing new challenges that constraints some of the adaptation strategies (Nassef *et al.* 2009; Ericksen *et al.* 2013). As a result, their livelihood systems are increasingly becoming vulnerable to external climatic shocks and stresses, leaving them with no any other option than to depend on frequent and or almost permanent relief interventions, and unsustainable social protection schemes by governments and humanitarian agencies.

According to Brinkman and Hendrix (2011) famine has become increasingly common since 1990s and is undermining food security in entire northern Kenya. Further, the negative impacts associated with climate variability and changes are compounded by many other factors, including widespread poverty, violent conflicts, livestock disease outbreaks and land degradation. In addition to increasing population growth which is projected to double the demand for food, land, water and forage resources in the near future (Davidson *et al.* 2003). Other compounding factors include human diseases such as HIV/AIDS, poor infrastructure and decades of marginalization by the national government. The majority of people in northern Kenya live below the absolute poverty line, for example, an estimated 87.5% of the population lives in absolute poverty, and more than 50% heavily relying on food aid and safety net programmes from year to year in Turkana County (Kenya National Bureau of Statistics-KNBS 2013). The people who are already poor in these remote parts of the country are struggling to cope with the extra burden of increasingly unpredictable weather, which is triggered by climate variability and change. However, little evidence is available on how climate variability and change impacts on pastoralists' vulnerability and adaptation options at a micro-level in the rangelands of Kenya. A few exceptions exist such as Galvin *et al.* (2004), Maddison (2007), and Silvestri *et al.* (2012) which examine farmers' perceptions of climate change, adaptation measures, and factors influencing farmers' decisions to adapt in Kenya.

Therefore, this study was undertaken to analyse climate variability and change on pastoralists' vulnerability and adaptations for integration into the knowledge of climate change science. This is particularly important for designing effective adaptation strategies to reduce risk associated with climate variability and change in the arid and semi-arid zones.

1.3 Justification

A number of climate variability and change impact studies have been conducted on specific sectors such as water resources, agriculture, health, and rangelands ecosystems by using impact models and to a lesser extent socio-economic analyses (Smit and Wandel 2006; Eriksen and O'Brien 2007; Nassef *et al.* 2009). Global recommendation for Africa calls for an integrated assessment approach for vulnerability studies, at a more micro-scale to account for the influence of local contexts

(Intergovernmental Panel on Climate Change IPCC 2014). From the perspective of pastoral households, an understanding of vulnerability to climate variability and change is needed at the level that would specifically address specific geographic location so that the communities will get adequate lessons to tackle climate change challenges with the precision that is necessary (Klein 2004). However, most of the scientific literature and discourses on vulnerability has concentrated on contributing to theoretical insights or analysis at a regional or national scale, with findings for each region, which have implication more for system wide planning (Fussel and Klein 2006; Hinkel 2011). For example, the sensitivity of agricultural systems (Galvin et al. 2004; Nhemachena and Hassan 2008; Roncoli et al. 2010; Bryan et al. 2013) or species (Thornton et al. 2006) to climate change have been examined in detail. While there is no superior scale of climate vulnerability analysis, recent studies by Yuga et al. (2010) and Marshall et al. (2014) have confirmed that micro-level analyses have been largely overlooked in favour of ecosystem-scale studies of biophysical vulnerability.

Hitherto, there is ambiguity and paucity of scientific information and in-depth analysis on household's vulnerability and change in adaptation strategies to climate variability in the ASALs of Kenya (Bryan *et al.* 2013). This study was therefore designed to provide more clarity on the scientific knowledge needed to strengthen households' adaptation strategies in response to the increasing climate variability and change in arid environments. Therefore, the current study contributes to the understanding of influence of climate variability and change on vulnerability and adaptation strategies from a pastoralist point of view. The study further explored vegetation response to precipitation anomalies in the study area. This analysis is crucial for enhancing effective adaptation strategies to confront future extreme climate events, and to update current science, public knowledge and policy discourses on climate change.

1.4 Objectives

The overall objective of this study was to better understand pastoralists' vulnerability and adaptation strategies to climate variability and change, as well as vegetation responses to precipitation anomalies in an arid and semi-arid environment of Turkana County, Kenya.

The specific objectives of this study were to:

1. Analyse rainfall and temperature trends, seasonal changes and occurrence of extreme climate events in Turkana County.
2. Investigate local community adaptation and coping strategies to climate variability and change.
3. Develop a predictive model for assessing households' vulnerability to climate-induced stresses in the study area, and
4. Assess vegetation response to precipitation anomalies in the study area.

1.5 Research Hypotheses

The study was guided by three hypotheses, namely:

1. There has been a significant long term change in rainfall and temperature trends pattern in the study area.
2. Pastoralists' vulnerability to climate variability and change is not influenced by socio-economic and environmental factors.
3. There is no significant correlation between rainfall anomalies and vegetation responses in the study area.

1.6 Conceptual Framework

1.6.1. Vulnerability and resilience

Studies from existing frameworks suggest that households' vulnerability to climate variability and change depends on the availability of resources, household characteristics, existing political institutions and social networks as well as environmental context (Brooks *et al.* 2005; Ifejika *et al.* 2014). The integrated framework focused on adaptive capacity of households which consists of access to assets, transformative structures and processes as well as diverse adaptation strategies (Frankenberger *et al.* 2012). However, in the face of climatic disturbances such as drought events, the vulnerability framework is more relevant because they integrate the livelihood framework with components on risk management and climate change adaptation (Fraser *et al.* 2011). Figure 1.1 illustrate conceptual framework for building households resilience (flipside of vulnerability) to climate variability and change. The integration of risk-based approaches is therefore desirable if we are to address the numerous threats pastoral livelihood systems face as a result of climate variability and change. Nonetheless, the fact that vulnerability is context specific and multi-dimensional highlights complexity that runs through the vulnerability measurements and analysis literatures.

The Intergovernmental Panel on Climate Change - IPCC (2012) defines vulnerability to climate change as “the degree, to which a system is susceptible to, or unable to cope with adverse effects of climate change, including climate variability and extremes. Vulnerability is therefore a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and adaptive capacity. The vulnerability framework lays emphasis for understanding the adaptive capacity of households and communities to respond to disturbances such as drought, floods, disease outbreaks and conflicts, and how such disturbances affect households’ exposure to risk, which results either in increased vulnerability or increased resilience over time (Tschakert and Dietrich 2010). The framework comprises the interaction between exposure, sensitivity and capacity to adapt.

Exposure in the context of vulnerability is a function of magnitude, frequency, duration and spatial extent of shocks and stress (IPCC 2014). Shocks can be one-off extreme events of short duration (no more than a few minutes, hours or days), such as disease outbreaks. On the other hand, stress is a long-term trend that undermines the potential of a given system and increases the vulnerability of actor within it to adverse effect e.g. droughts. The inability to cope with seasonal shocks or stresses can make already vulnerable households even more vulnerable by increasing their risk of exposure to future hazards (O’Brien *et al.* 2004). Adaptive capacity is discussed as the ability of a system to evolve in order to accommodate hazards (Cutter *et al.* 2003; Galloping 2006). Similarly, it encompasses ability for households to plan, prepare for hazards, facilitate and implement adaptation measures.

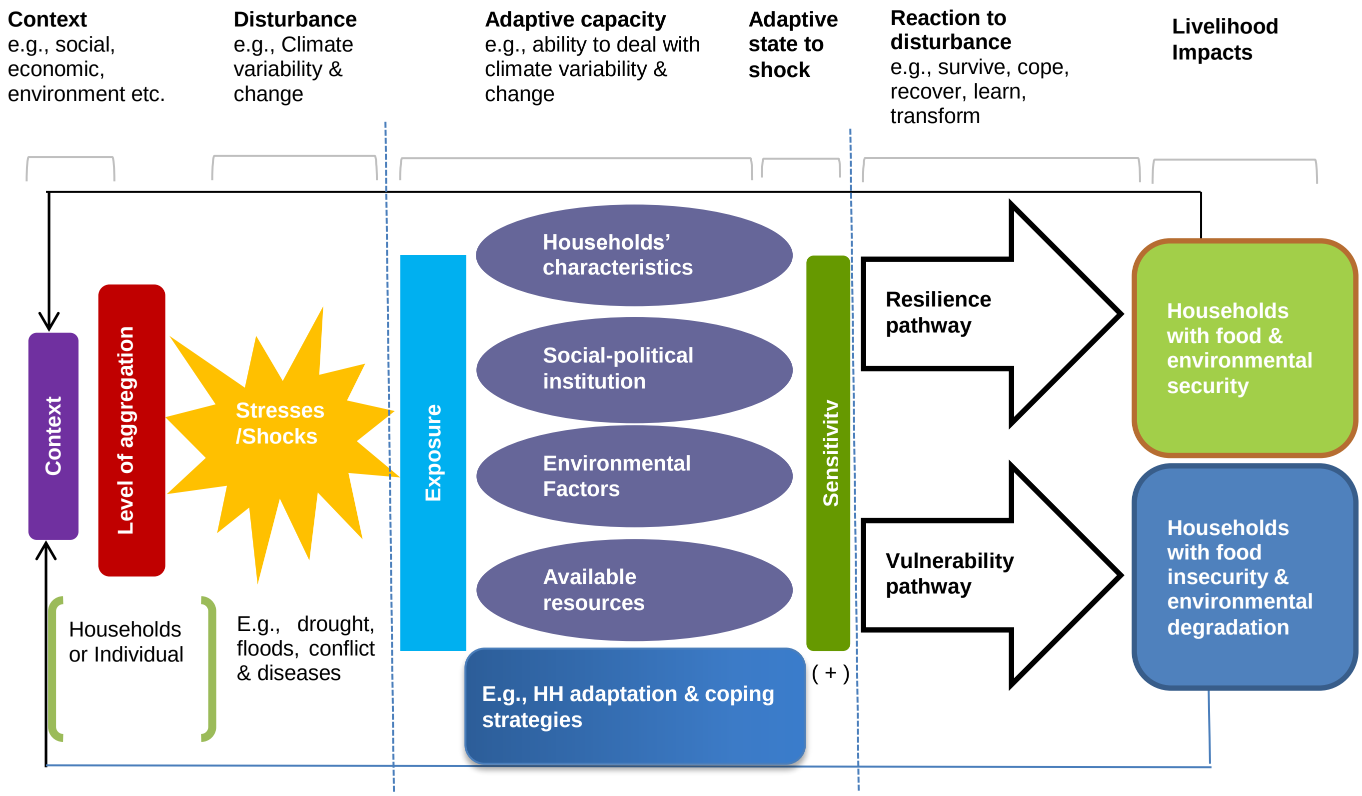


Figure 1.1 Conceptual framework for building households resilience to climate variability and change (Adapted from Disaster Resilience Framework in Frankenberger *et al.* 2012)

Factors that determine adaptive capacity of individuals revolve around household characteristics, social networks and political institutions, bio-physical and environmental factors. Vulnerability is influenced by the build-up or erosion of the elements of resilience that determine the ability of a household to absorb stresses, and maintain essentially the same structure, function and feedbacks (Adger 2006). As such, vulnerability is a function of macro (economic, institutional and environmental setting) and micro (access to resources, adaptation and coping strategies) factors at household level. A useful conceptual framework for vulnerability should not only describe the current state of the system under analysis (households), but should also capture a complex dynamics and sensitivity which is the degree to which a system is modified or affected by perturbations (Galloping 2006).

The resilience and vulnerability pathways (Figure 1.1) are viewed as processes rather than static states of a system. Households or communities' that are able to use their adaptive capacity to manage the shocks or stresses they are exposed to and incrementally reduce their vulnerability are less sensitive and are on a resilience pathway. In contrast, households that are not able to use their adaptive capacity to manage shocks or stresses are sensitive to shocks and stresses are likely to go down a vulnerability pathway. The livelihood outcome depends on the needs and objectives that households are trying to realize. Resilient communities and households are able to meet their food security needs, have access to adequate nutrition, well protected environment and income security, health security, and are able to participate in the decisions that affect their lives (Frankenberger 2012*)*. Vulnerable households experience deficits, or a high risk of deficits in each of these aspects. This study is framed to enhance understanding of the local adaptive capacities in shaping the sensitivity of households' exposure to climate variability and change, based on the vulnerability and resilience conceptual framework.

1.6.2 Hypothesized theory of pastoral households' vulnerability to climate-induced stresses

In this study, the Driver, Pressure, State, Impact, and Response (DPSIR) model was used to explicitly explain cause and - effects relationship on how pastoralist households are impacted by climate variability and change (Figure 1.2). Climatic extremes, particularly recurrent drought hazards have resulted in depletion of water and pasture resources which are critical for pastoral production systems in the rangelands (Schilling *et al.* 2012). The incidences of severe, recurrent droughts seem to be on the increase resulting in deaths of large numbers of livestock, resource based conflicts, livestock diseases outbreaks and environmental degradation. In addition to drought, other important risk include human population pressure and settlements, land use changes and exploitation of key resources, disease outbreaks, raids and conflict are all restricting access to critical livestock grazing areas in the arid and semi-arid lands (ASALs) of Kenya. Such are taking place under the backdrop of inadequate infrastructure, poor market linkages, and inaccessible institutions. As a result, pastoralists are likely to be more exposed to the effect of climate variability and change.

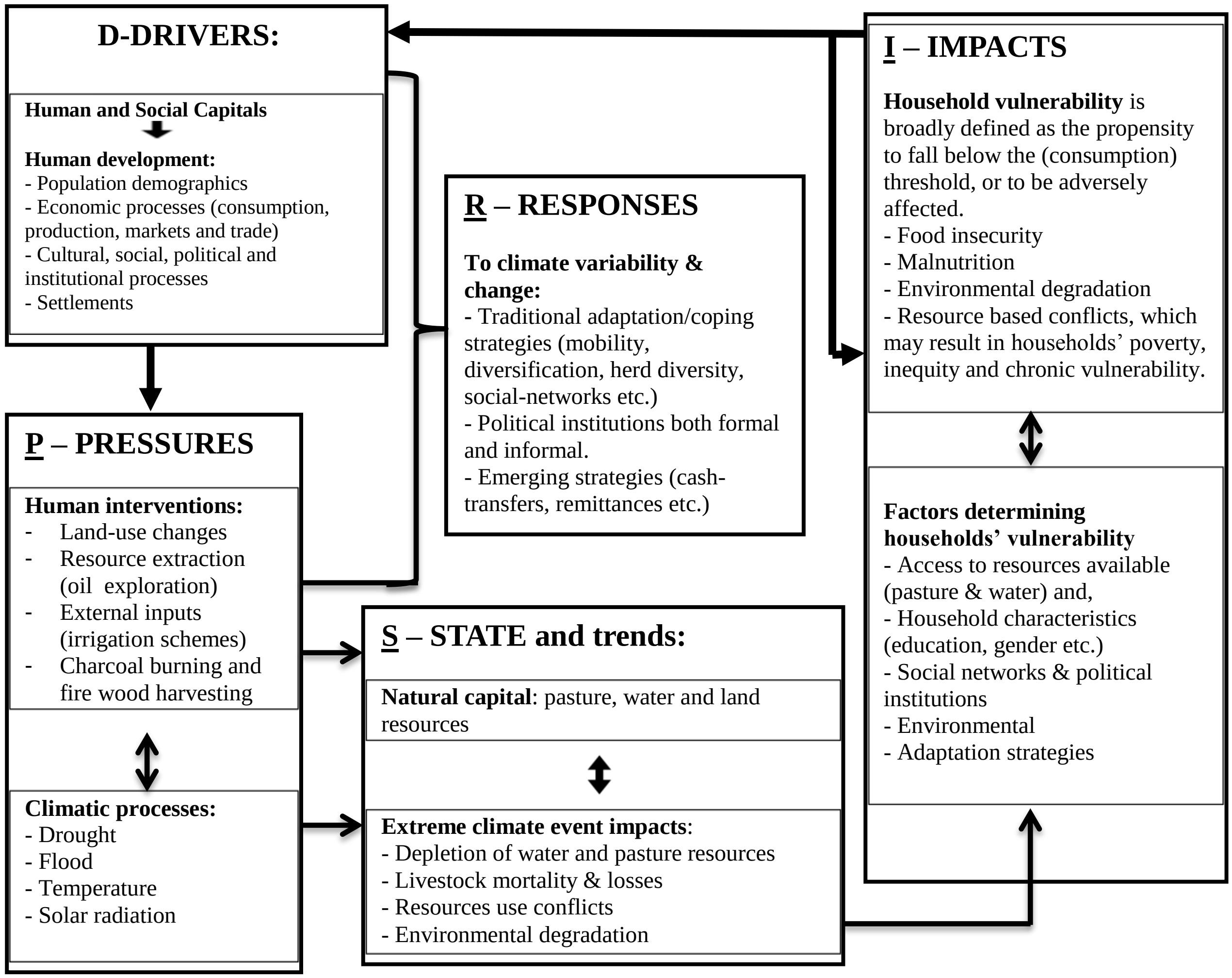


Figure 1.2 The DPSIR model for pastoralist household's cause and – effects relationship with climate variability and change

Climate variability in Kenya's ASALs is not a new phenomenon. Crises liked to climate extremes like droughts have been traced back as far as 1950s (Hadley 2012). However, the drought cycle has changed in recent time and become more frequent, giving no time for households to recover from the effects (Huho and Kosonei 2014).This has resulted in economic, environmental, social and cultural losses in the pastoral areas of Kenya. In most cases, pastoralists spread risks and uncertainty through herd mobility to make best use of the heterogeneous landscapes, keep diverse mix of livestock species, restock and destock (Watson and Binsbergen 2008). In addition, households have developed a number of response mechanisms in order to live with climatic variations and uncertainty, such as diversification to crop-farming, wage labour, reliance on remittances and social networks of support. Unfortunately, these strategies that have served the vulnerable households very well in the past are presently constrained in the light of frequent droughts, rapid social and economic changes and deteriorating climatic trends. That notwithstanding, it is widely acknowledged that some of the strategies used by pastoralist if strengthened may effectively address vulnerability to climate variability and change, and ultimately enhance households' climate resilience.

Using this theoretical model this study contributed in deepening understanding on identification of stresses and shocks that trigger pressure on households. The study helps to identify the climate induced processes that interact in an arid environment to impact on pastoralist livelihood system. It also contribute to scientific understanding of the specific response adaptation and coping strategies that pastoralists are using to cope with climate-induced disturbances for more effective targeting of policies and resilience programs.

1.7 Organization of the Study

This study is presented in nine chapters as illustrated in the thesis organization (Figure 1.3). Chapter One presents general background to the study. The chapter also describes climate variability and change within the study context, and presents the research problem under investigation, objectives, hypothesis, detailed conceptual framework used and the organization of the study. Chapter Two reviews literature on climate variability and change to highlight changing adaptation strategies by Turkana pastoralists of north-western Kenya. Chapter Three provides a detailed description of the study area, and general methods used in this study. In Chapter Four, the trend of rainfall and temperature variability in arid environment of Turkana is analysed. Chapter Five investigates the existing adaptation and coping strategies employed by the Turkana pastoralist. The chapter also highlights in details the long-term and temporary adjustments by pastoralist in terms of livelihood activities when faced with drought stresses. The determinants of pastoralist perceptions on climate variability and change, and adaptation are identified in Chapter Six. Further, Chapter Seven introduces a concept of measuring household vulnerability to climate-induced stresses with implications for resilience programming in the pastoral rangelands.

The link between vegetation dynamics and precipitation anomalies in the Turkana rangelands are discussed in Chapter Eight using satellite and actual precipitation datasets. Lastly, Chapter Nine summarizes the research findings and the main conclusions from all the chapters, implications for practice and potential areas for future research based on the major study findings.

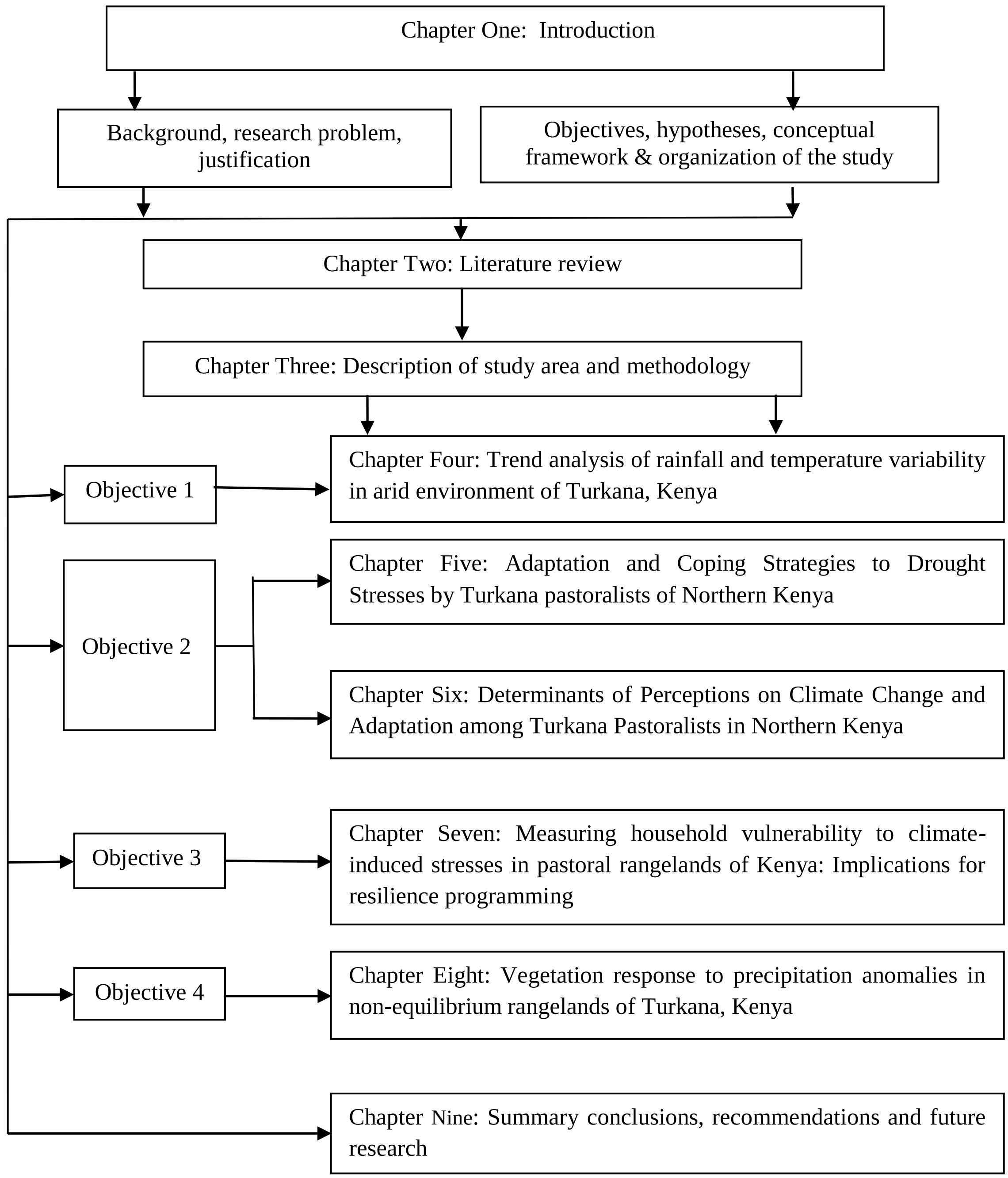


Figure 1.3 Thesis organization

CHAPTER TWO

LITERATURE REVIEW

2.1 Background

The purpose of this chapter is to review literature on pastoralists' vulnerability to climate variability and change in order to understand changing adaptation strategies by the Turkana pastoralists for integration with the domain of climate resilience. Climate variability and change has significant impacts on human and natural systems due to increasing occurrence of uncharacteristic extreme weather events and the intensification of both frequency and severity of climate stressors, such as drought (Hulme *et al.* 2001). The manifestations of climate variability and change have the potential to directly and severely impact communities that rely on climate-sensitive production systems like pastoralism (Bryan *et al.* 2013; Nicholson 2014). The increasing frequency of drought events as observed between 2008 and 2009, and thereafter in 2010 to 2011 underscored the need to examine adaptation strategies for long-term resilience to drought. Studies in the region show that vulnerability to drought, is arguably increasing on the back of climate variability and change, and violent conflicts providing compelling justification for effective adaptation strategies in the Horn of Africa (Smit and Pilifosova 2001; Paavola 2008; Headey and Ecker 2013).

There are predictions that due to accelerated anthropogenic and man-made activities, climate variability may increase in the future and that extremes might become more frequent in sub-Saharan Africa (Intergovernmental Panel on Climate Change IPCC 2014). The increased climate variability under projected scenarios is expected to augment vulnerability in the tropics, unless key investments are made to improve adaptive capacity of communities. Concern has been raised about viability of pastoralism which is practiced in sensitive environment characterized by high spatial and temporal variability in rainfall, and thus thought to be highly vulnerable to both present and future climate variability (Conway *et al.* 2005; Little 2012). However, contrasting past and present adaptation responses of pastoralist communities with those that are likely to be required in the future could give some indication of where the greatest stresses and transformation processes will lie for long-term climate resilience building. Pastoralist populations have always been highly adaptive, a necessary trait given the weather variability that is characteristic of the arid and semi-arid ecosystems in which they inhabit in East Africa (Galvin 2009). Nonetheless, climate variability and change is forcing new levels of transformative adaptations among pastoral communities, and many are significantly affected by the consequences of their coping and adaptations strategies (Tsegaye *et al.* 2013). This raises the question to what extent past and present responses of pastoral communities and their system to climate variability and extremes facilitate their long-term adaptation to projected climate scenarios. Other studies have showed that adaptation to climate variability is necessary both to reduce current vulnerability to climatic extremes as well as to prepare for future climate variability and change (Adger *et al.* 2005; Notenbaert *et al.* 2013). While some adaptations may be developed specifically to cope with climate variability and projected change such as climate-proof infrastructures, adaptations often also involve policy, legal, institutional and financial responses to reduce sensitivity and increase adaptive capacity for resilience (Ford *et al.* 2013).

In this chapter published journal articles, government statistics, empirical evidences from case studies and other technical materials was synthesized to highlight climate variability and change, and draw lessons from previous and past adaptation strategies to climate stressors for Turkana pastoralist of north-western, Kenya. In elucidating the information, the paper draws from integrated analytical theoretical frameworks on vulnerability (Kelly and Adger, 2000; O'Brien *et al.* 2004; Eriksen *et al.* 2005; Adger 2006; Fussel 2007; Reed *et al.* 2013), conceptualization of adaptive capacity (Smit and Wandel 2006; Gallopin 2006; Taylor 2013), and resilience science (Carpenter *et al.* 2001; Folke 2006). In light of these literatures, the concepts of vulnerability, adaptive capacity, resilience, exposure and sensitivity are all interrelated and have wide application to climate change adaptation science. The changing climate conditions, especially the increased frequency and or severity of extreme events, will no doubt increase vulnerability to natural disasters such as droughts. At the same time, adverse climate impacts are considered disasters when they produce widespread damage and cause severe alterations in the normal functioning of community systems (Intergovernmental Panel on Climate Change IPCC 2012). However, the severity of impacts depends not only on the climate extremes but also on exposure, sensitivity and vulnerability of a community or a system (Gallopin 2006). In most instances, adaptation to climate variability and change focus mainly on reducing exposure and vulnerability `and increasing resilience to the potential adverse impacts of climate variability and extremes (Smit and Wandel 2006), even though risks cannot fully be eliminated. Despite numerous interpretations, the Intergovernmental Panel on Climate Change (IPCC 2012) report considers climate extremes as the occurrence of weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable.

This chapter discussed how Turkana pastoralists have responded to frequent drought episodes and other climate stressors by keeping different types of livestock species, diversifying livelihood strategies, resources management and herd's mobility, sending children to school, migration to gain access to wage labour and self-employments. However, some of these strategies are challenged by emerging social, political, economic and environmental context which is likely to be different from the past context within which pastoralist communities have operated for centuries. For example, the depletions of the pasture resources and scarcity of water for livestock further complicate the ability of communities to live with climate variability and change (Ericksen *et al.* 2013). This is particularly problematic to vulnerable groups such as children, rural women and the elderly whose access to adaptation strategies is limited. In the past before 1970s, pastoralists in the Horn of Africa lived more sustainably through a series of institutionalized adaptive strategies where flexibility in time and space for accessing pasture and water resources was crucial, with strategies of herd diversification, discreet off-take rates that focused on selling male animals and less reproductive females, and exchange relationships with other nomads and sedentary households (Behnke and Scoones 1993; Little 2012).

The second section of this chapter examines climate variability, extreme drought events and projected climate scenarios in Turkana, and the Horn of Africa in general. The third section discusses various livelihood strategies and elements that make the Turkana community able to withstand climate variability and extreme weather events, especially the recurrent drought episodes which has increased in frequency in the last two decades 1990s and 2000s. Then the fourth section reviews vulnerabilities and adaptation strategies to changing climate, while the fifth section examines policy environment for future adaptation to climate variability and extreme events in Turkana. The last section of this literature review highlights critical conclusions.

2.2 Climate Variability and Drought Impacts

Drought events are the most important characteristic of climate variability and change in Turkana County. The region has experienced major incidences of droughts since 1960s, which have become more common from the late 1990s and 2000s. The following years 1960/1961, 1969, 1973/1974, 1979, 1980/1981, 1983/1984, 1991/1992, 1995/1996, 1999/2000, 2004/2006, 2008/2009, and 2010/11 had prolonged droughts with widespread direct and indirect effects on the lives and livelihoods (Osano *et al.* 2013; Huho and Kosonei 2014). Further evidences from other climate models corroborates that there have been more Meteorological drought events in the Horn of Africa which are set to escalate in frequency and intensity in the future (Nicholson 2014). The challenges of recurrent droughts pose considerable challenges to the people of Turkana. Previous studies showed that drought is one of the main catalysts of food insecurity and malnutrition in the rangelands (Western *et al.* 2010; Huho *et al.* 2011). The impacts of droughts on local population are manifested mainly through livestock mortality, water scarcity and land degradation. The drought impact is amplified by increasing human population, privatization of communal lands and the associated sedenterisation, violent conflicts, weak governance, and reduced adaptive capacity of the households. These processes jointly heighten the vulnerability of pastoral communities, with increased poverty as a possible outcome (Eriksen and O'Brien 2007). The poverty which is an obstacle to effective adaptation in turn increases vulnerability of pastoralist to climate variability and change, a positive feedback mechanism which further deepens poverty.

Turkana County will undoubtedly continue to experience a mixture of climate variability and extremes that are predicted for the greater Horn of Africa as a whole. Recent climate observation and modelling studies suggest median temperature increases which is likely to exceed 3^0C throughout Africa, including Kenya by the end of the 21st Century, roughly 1.5 times the Global mean response (Hulme *et al.* 2001; IPCC, 2007). There is inconsistency in prediction of distribution in some of the future climate changes in Kenya due to incomplete understanding of the climate system and its inherent unpredictability. However, there is scientific consensus that dry seasons will warm more than wet seasons and the country's interior like the northern ASALs is likely to experience higher temperature increases than coastal regions (Thornton *et al.* 2006a). The global climate models predict shifts in rainy seasons, intense rains, and rainfall variability by up to 5-20% in Kenya by the year 2030 (World Wide Fund - WWF 2006). Changes in temperature and rainfall of this magnitude are likely to have a range of impacts on people, particularly those who derive a large portion of their livelihoods from weather dependent production systems such as pastoralism.

Increase in warming and rainfall variability would cause changes in water resources. For example, a 10% drop in rainfall as suggested by regional predictions in areas of less than 500 mm per year will result in a 50% decline in surface drainage (Hoffman and Vogel 2008). Such a dramatic decline in surface drainage would have devastating consequences in ASAL which covers 89% of the total land mass in Kenya (ASAL Policy 2012). Therefore increasing demand of water for livestock and people will is likely increase tensions around scarce water and pasture resources. Similarly, rainfall and temperature are key determinants of ASAL productivity. The effect of future climate change projections, especially of temperature and rainfall, is likely to have considerable impacts on the length of the growing period (LGP) for pasture and other important vegetation species in the rangelands (Thornton 2006a). A significant reduction in LGP by 2050 has also been predicted in most models for the more arid and semi-arid parts of eastern Africa (Thornton *et al.* 2006b; Fischlin *et al.* 2007). Predicted changes in rainfall evaporation may also decrease water level and pose risks to drinking water quality. Therefore, the reduced water availability will require more time for water collection and reduce water use, which impairs hygiene and increases the incidences of contagious diseases (Paavola 2008). Adaptive water management techniques, including scenario planning, learning-based approaches, and flexible and low-regret solutions, can help create resilience to uncertain hydrological changes and impacts due to climate change.

Moreover, change in forage quality and composition is expected in light of the predicted increases in temperature and lower rainfall in the tropics. Temperature, rainfall and atmospheric carbon dioxide concentration interact with livestock grazing and land cover change to influence rangeland quality and composition (Hoffman and Vogel 2008). Increased temperature, for example, not only increases drought stress in plants but also enhances lignification of their tissues which affect both its digestibility as well as its rate of decomposition (Thornton 2006a). In addition, the amount and timing of rainfall also has an important influence on rangeland species composition in both short and long-term, primarily through its differential effect on the growth and reproduction of key forage species. An extended drought can result in the mortality of perennial plants and the switch to an annual dominated flora (Coughenour and Ellis 1993; Hein 2006). Drought diminishes the quantity and quality of pasture forcing pastoralist to migrate.

In addition, the general reduction in productivity which is projected for Kenya's ASALs such as Turkana will have important negative consequences for economic development potential of these area and will likely result in a shift in sectorial activities (Hulme *et al.* 2001; Easterling *et al.* 2007). Some projections suggest that decrease in the length of the growth period (LGP) and an increase in rainfall variability will render crop cultivation too risky and will result in a switch to more extensive livestock production systems (Thornton *et al.* 2006a). There is also likely to be a switch on species (for example from cattle to sheep, goats and camels) which are better adapted to more arid climatic conditions (Hulme *et al.* 2001; Easterling *et al.* 2007). Other changes include a greater frequency of loss of livestock assets as observed during the 2008/9 and 2010/11 drought events in the Horn of Africa. For example, during the 2008/9 widespread drought in Kenya, the livestock mortality was estimated at 40-70 per cent of the total herd (Zwaagstra *et al.* 2010). Like in most parts of the ASALs, loss of livestock was largely caused by starvation.

Temperature and rainfall are important variable on livestock grazing and stocking strategies. However, other factors influencing decision making, are also key in shaping pastoralist production systems (Brooks 2006). Rather than singular stressors like drought shaping and dominating the environment, a range of other factors also need to be understood including the interaction of human settlements, climate change, and changes in land tenure impact on lives and livelihood. In Turkana and pastoral areas in general, much more work is required on how policy and understandings of climate changes are framed, reproduced and mainstreamed into practice.

These various interactions can act as critical drivers of vulnerability as well with potential challenges including conflicts between different land use sectors.

2.3 Livelihood Strategies in Turkana

The description of each identified livelihood zone is shown in Table 2.1. The Turkana community largely depends on pastoralism system as their main livelihood production activity, which is made up of people, natural resources, livestock and social relations. Pastoralism is the principle livelihood and is assumed to have existed for more than 9,000 years in Turkana (Eaton 2010). Approximately 70% of the populations inhabiting the area are nomadic or semi-nomadic pastoralists. Turkana County is thought to have some of the highest number of livestock population in Kenya (Republic of Kenya 2010). The nomadic transhumance practiced by this ethnic community is characterized by risk-spreading and flexible mechanisms, such as mobility, communal land ownership, large and diverse herd sizes, and herd separation and splitting (Schilling *et al.* 2012). The livestock types kept to manage and spread risk include cattle, camels, goats, sheep and donkeys. Data obtained from Government statistics revealed a significant increasing trend for sheep and goats, while camel, donkey and cattle showed no trend pattern for the period 1993-2009 in Turkana (Table 2.2). Although there was no significant increase in camel population, the observed data indicate that their numbers have been on the increase, partly due to changing vegetation condition that favour browsers. The livestock species have different forage and water requirements with variable levels of resilience during drought periods. Livestock possession plays multiple social, economic and religious roles in pastoral livelihoods, such as providing a regular source of food in the form of milk, meat and blood for household members, cash income to pay for cereals, education, health care and other services. The Turkana livestock is also essential for payment of dowry, compensation of injured parties during raids, symbol of prosperity and prestige, currency for exchange, store of wealth and security against drought, disease and other calamities. Livestock is therefore an integral form of pastoral capital, besides functioning as a means of production, storage, transport and transfer of food and wealth (Behnke and Muthami 2011).

Table 2.1 Livelihood zones estimated human population in Turkana County

Livelihood zone	Population*	Description
Central pastoral	243,979	Livestock provide the main source of food and cash income for roughly 80% of the population of this pastoral livelihood zone. The remaining population is heavily dependent upon a combination of self-employment activities (charcoal, mat and basket making, brewing etc.), and relief food. Compared to the border pastoral zone, this zone has less grassland, with fewer cattle and more camels are kept.
Border pastoral	315,101	This zone receives more rain, has more pasture and more heads of cattle compared to the Central pastoral zone. Given its proximity to the border, the zone is insecure, and has poor market access and limited access to social services such as health facilities and schools. Livestock and its product sales are key income earning activities for households in this zone.
Kerio riverine	99,657	Crop and livestock production (meat, milk and grain bought through livestock sales) are the basis of the riverine economy. This ecosystem is fed by rainfall from Cheringani Hills. This highland source creates sufficient water flow both for irrigation and for pasture growth, sustaining herds and farms. However, the zone does not support large herds because of frequent raiding and resource pressures around the settlements which limit the numbers of livestock kept.
Turkwel riverine	58,641	This zone along the Turkwel River is an agropastoral, where households both grow crops and rear livestock, in addition to pursuing other income generating activities like charcoal production and bee keeping for sales. The population is predominantly former pastoralists who previously only engaged in opportunistic farming. Crop production relies on both rainfall and irrigation from the Turkwel River. The main crops grown are sorghum, maize, green grams, cowpeas, vegetables, watermelon, pumpkins, gourds and bananas. The main types of livestock kept are goats and sheep, although some households also keep cattle, camels and poultry and a few households keep donkeys.
Lake Fishing	60,802	Fishing is the main economic activity of the zone on the western shore of Lake Turkana, despite the populations' pastoral background. As such, the most valuable productive assets are fishing equipment (nets, lines and hooks), whereas the importance of livestock to household income is relatively small in this zone. Fish is either sold fresh, dried, salted or smoked depending on the distance to the market. The main fish trading centres are Loarengak and Kalokol.
Urban	236,920	Livelihoods in this zone are wage labour-based. Many households rely on the natural resources available i.e. selling firewood, charcoal, collecting hard-core, ballasts, weaving/basketry. Casual unskilled and skilled labour opportunities associated with Lodwar's shops and businesses provides residents with a variety of income earning opportunities. The presence of many humanitarian organizations, government offices and UN agencies offers formal employment opportunities. Production of crops and livestock products is minimal within this livelihood zone. Almost all households get the bulk of their food from the market. In addition to market-purchased food, some households receive food aid and other social protection support from agencies.
Total	**1,015,100**	

Source: Author compilation based on Household Economic Assessment (HEA) report for Turkana in June 2012.

Table 2.2 Estimate of livestock population in Turkana County

Livestock type	Tropical Livestock Unit-TLU (1993-2009) 1993	1996	1999	2002	2005	2008	2009	P-values (Deviation from linearity)	Trend
Sheep	33,443	89,200	98,333	97,560	105,440	105,450	127,406	0.003*	Increasing
Goat	93,345	178,867	196,667	195,120	202,100	202,100	187,469	0.001*	Increasing
Cattle	107,345	141,372	164,136	135,520	138,530	138,530	176,560	0.219	No trend
Camel	63,153	114,192	144,960	140,760	172,400	172,400	196,185	0.329	No trend
Donkey	12,321	14,000	17,132	13,056	14,064	14,064	18,015	0.169	No trend

*significant at 5% (*p<0.05); TLU Tropical livestock unit (1 TLU = 250 Kgs);

Over the last two decades, the incidences of severe, recurrent droughts have resulted in the deaths of large livestock numbers as pastures and water sources dry out in the area (Zwaagstra *et al.* 2010). The Turkana pastoralists, however, utilize multiple livelihood diversification strategies, institutions and networks for contending with the environmental uncertainty and extreme weather events like droughts for years (Watson and Binsbergen 2008). Presently, with changing climatic conditions, pastoralists have had to employ other supportive activities to supplement pastoralism, which is constrained and not able to effectively meet all their economic and social needs (Pike 2004). However, the existence of distinct livelihood zones plays a critical role on livelihood strategies employed, for example north-western part is predominantly used for nomadic pastoralism where cattle, camels, goats, sheep and donkey utilize throughout the year. The Turkwel/Kerio riverine and north-western part of the county are used for both crop farming and dry season grazing areas, while around Lake Turkana is a fishing zone (Table 2.1). All the livelihood zones complement each other and are crucial for community survival during extreme weather and drought episodes.

Crop farming has been acclaimed as a viable climate risk management and livelihood strategy for the sedentary farmers and agro-pastoralist (Smith 1998) others on the other hand view it as an unsustainable (even destructive) option for the rangelands especially with the challenges of climate variability and change. That notwithstanding, the people of Turkana cultivate staple crops predominantly for own consumption but also sell what they produce along Turkwel and Kerio riverine ecosystem, which are suitable for crop and fodder production. These two major rivers crossing the county are fed by rainfall from the Cherigani Hills. With increase in the sedenterisation of pastoralist, there has been evidence of large areas being opened up for irrigation schemes along the riverine with donors support. The establishment of irrigation schemes is seen as opportunity for livelihood diversification. However, from year to year, production outcomes have been highly variable and the schemes often require extensive rehabilitation efforts. For instance, the cultivation of cash crops such as cotton previously grown at Katilu irrigation scheme has since stopped (Watson and Binsbergen 2008), and today the most important staple crops grown along riverine ecosystems include maize, sorghum, millet, cowpeas, green grams, a variety of vegetables and fruit crops such as mangoes, citrus, bananas and dates.

Fishing in Lake Turkana is another form of livelihood diversification. However, small-scale fishing among the pastoralist has often been perceived as a 'livelihood of last resort', for the pastoral drop-outs. This concept implies that fishing is chosen due to lack of alternative options and has led to suggestions that the livelihood activity is only for the very poorest households around Lake Turkana. The evidence from literature suggests that for many people living around the lake in Turkana, fishing is one economic element within a multitude of activities that constitute their livelihood diversification strategy. The fishermen along Lake Turkana migrate to follow the patterns of fish movement. The main fish types harvested in the lake are tilapia (*Oreochromis niloticus*), mudfish (*Protopterus species*), and Nile perch (*Lates niloticus*) and king fish (*Seriola lalandi*). The pastoralists also supplement their livelihoods income by selling fish. Unfortunately, the poor transportation and communication infrastructure restricts fishing trade and income generation opportunities around Lake Turkana. In addition, fishing in Turkana is likely to be affected by recurrent droughts and rising temperatures, conditions that starve the lakes of inflowing water and evaporate the water, leading to reductions in water levels.

The evidence from literature also suggests that households also tap natural resources available to cater for their subsistence needs and to earn cash income. The nature based incomes are derived from aloe vera (*Aloe turkanensis*) processing for soaps by community groups in Loima, Turkana west and Kalemng'orok in Turkana South. Trees are also harvested for construction poles, and production of firewood and charcoal for sale. Studies by Kariuki *et al.* (2008) observed that households around Kakuma obtain significant amount of their income from exotic and deadwood trees. Many pastoralists have also taken up weaving of mats and baskets especially near the lake where weaving material is readily available from the palm tree (Watson and Binsbergen 2008). The significance of natural resources is also felt by peri-urban households in Lodwar, Kakuma, Kalokol, Lokichar and Lokichoggio that are often visited by traders who offer markets for their products. Other natural resource-based livelihood diversification activities include collection and sale of *gum arabic* (Little *et al.* 2001) and honey.

Non-farm income from wage employment and self-employment has increasingly become more important for the younger generations while the significance of nomadic pastoralism and crop farming seems to be declining as the main form of livelihood income in the area (UNDP 2014). According to the County Integrated Development Plan (CIDP 2013), the wage earners make up approximately six percent of the entire population. The persons are employed in sectors ranging from education, government, domestic to humanitarian organizations. The proportion of persons with self-employment is very low since majority of the population prefer wage employment. Despite numerous conflicting literatures on non-farm activities in Turkana, this study confirms that the pastoralists in Turkana are increasingly pursuing non-pastoral income strategies to meet consumption needs and to bolster their resilience against stresses caused by drought, livestock disease outbreaks, and insecurity (Silale and Nyambegera 2014).

2.4 Climate Vulnerability and Adaptation Strategies

Climatic volatility is obviously a defining characteristic of vulnerability in Turkana, and the Horn of Africa in general (Nicholson 2014). The climate studies by Intergovernmental Panel on Climate Change IPCC (2012) show that drought events have always been a regular and expected occurrence in the arid and semi-arid regions, and adaptation responses and strategies are the critical means of mitigating the effects of drought. Yet even with the complementary responses and adaptation mechanism, drought remains the overwhelming challenge to livestock herds and pastoral livelihoods. While the combination of large herd mortality and clear exposure to drought is certainly indicative of rising vulnerability to climate, livestock experts also emphasize that this increasing vulnerability is substantially the result of weakened coping mechanisms, particularly decreased mobility resulting from policy discrimination against pastoralism (Lind 2003; Little 2012). In contrast, evidence of adverse climate change would suggest that it is not policies or institutions alone that are contributing to increase in vulnerability.

Reviewed articles indicate that most Turkana pastoralists have adapted to the cyclic tendencies of droughts, and with time have come to rely on complex adaptation and coping strategies aimed at minimizing vulnerability and losses from drought or facilitating recovery thereafter (Watson and Binsbergen 2008; Schilling *et al.* 2012). The strategies includes complementary responses such as mobility, communal land ownership, large and diverse herds, herd separation and splitting, informal social security systems, and engaging in other livelihood activities like crop farming, fishing, charcoal burning, and wage labour. Unfortunately, some of these strategies that have served the vulnerable communities very well in the past are presently constrained in the light of the frequent occurrence of droughts, rapid social and economic changes and deteriorating climatic conditions. This is in addition to the presence of other factors such as violent conflicts, livestock and human diseases, social and economic marginalization, poor government policies, illiteracy and the displacement of pastoralists, which exacerbates their vulnerability amid the challenges already posed by climate variability and change in Turkana. However, it is well recognized that some of these adaptation and coping strategies used by pastoralist may effectively address several challenges besides climate variability and change. Figure 2.2 illustrate various internal and external factors that drive changes in the livelihood adaptation strategies of the Turkana’s.

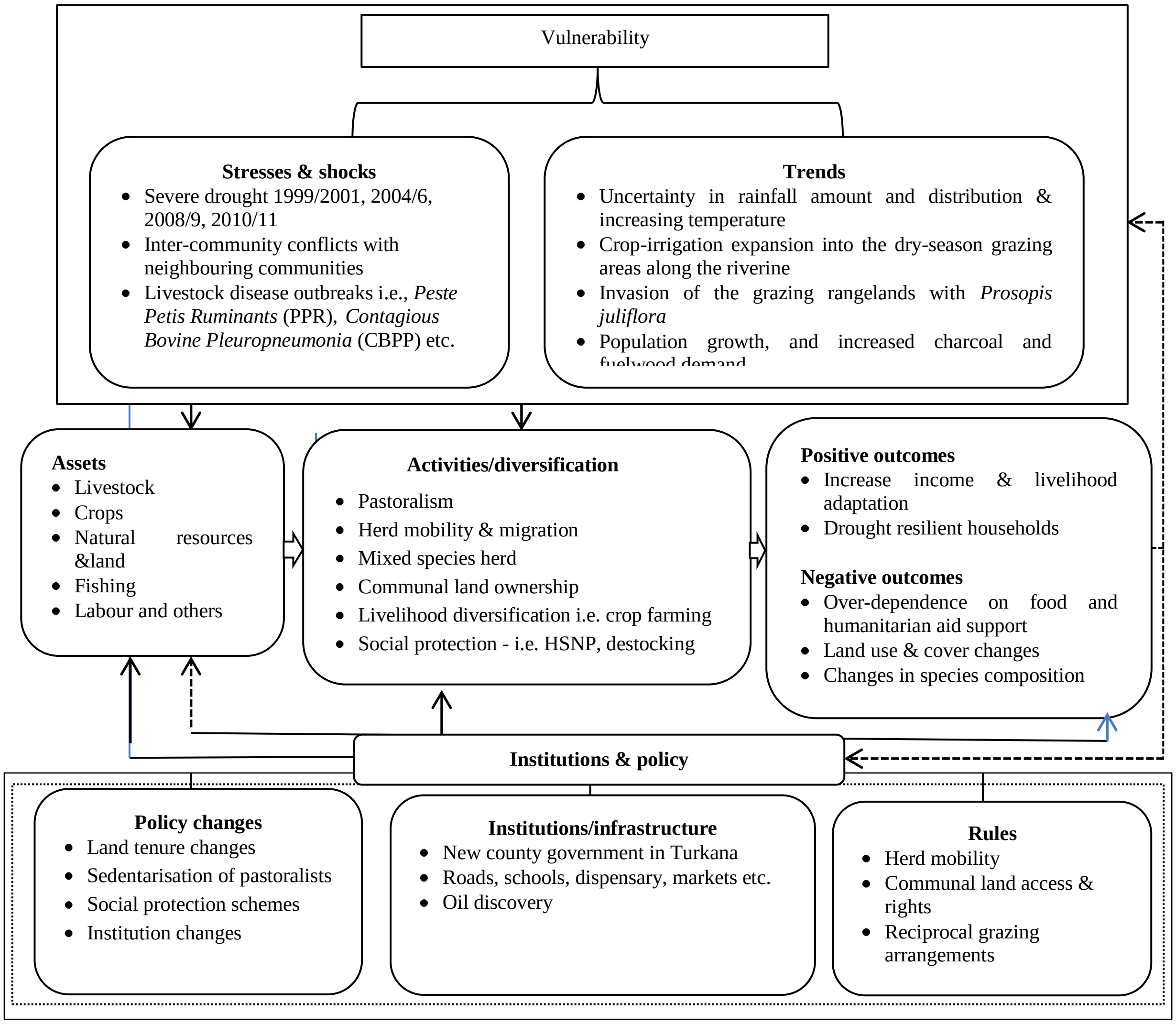


Figure 2.1 Schematic representation of conceptual framework for climate adaptation in Turkana County, Kenya (the solid arrows indicate direct influence, while the dotted arrow indirect impact).

Previous studies by O'Brien and Leichenko, (2000) and Adger *et al.* (2005) observed that rural communities' adaptations are not isolated from other household decisions, but occur in the context of demographic, environmental, cultural and economic change. Some adaptations can be clearly identified as being triggered by climate variability and change, and those adaptations are often purposeful and directed, while others can also arise as a result of other non-climate-related social or economic changes. For example, a pastoral household deciding to move from an area at increasing socio-political risk of conflict to a more secure area, may not be primarily motivated by climate events like drought, but rather by other either demographic, social or political factors. Clearly, attributing adaptations to climate variability and change at a community level is not a simple process especially within the highly unpredictable arid and semi-arid regions. However, irrespective of adaptation rationale, both purposeful and unintentional adaptations can generate short-term or long-term benefits to the climate affected communities. This article section seeks to demonstrate that the past and present adaptation experiences by the Turkana pastoralist can offer lessons for governments wishing to reduce vulnerability for long-term climate resilience interventions. Some of the adaptation strategies include:

Mobility: The traditional nomadic form of pastoralism based on strategic seasonal migration in response to fluctuations in resource availability including water and pasture, has long been giving way to transhumance pastoralism in Turkana. Although the pastoralist vision of the lifestyle and the identity it carries remain central despite realities that constrain or even threaten its future (Schrepfer 2014). The transhumance, is an adaptive mobility wherein part of the household and livestock herd are mobile (typically male adult household members and male and dry herd), while the remainder of the household lives in a permanent or semi-permanent setting (typically women and children with a herd dominated by lactating livestock) (Devereux and Scoones 2008; McPeak *et al.* 2011). Mobility is an inherent part of the pastoralist existence, and need to be understood as the strategic mobility of people and livestock. A part from seeking pasture and water for their animals, pastoralists also migrate for other economic purposes, to access livestock, markets or urban centres, and particularly if they have diversified their lifestyle. This form of migration is pursued primarily for livelihood purposes and is a matter of choice. Despite constraints, majority of Turkana herders are highly mobile with different migration routes and varying degrees of mobility (Mureithi and Opiyo 2010). According to McCabe (2004) the social networks amongst the herders offer security and insurance that is part of this flexibility. Mobility is therefore fundamental to appropriate adaptation to changing climatic condition and trends. In addition, studies show that ASAL ecosystems are healthier where mobile pastoralism continues to be practiced effectively (Niamir-Fuller 2000; Nassef *et al.* 2009; Agrawal 2010). Grazing opens up pastures, stimulates vegetation growth, fertilizes the soil and enhances its water infiltration capacity as hoof action breaks up the soil crust, aids in seed dispersal to maintain pasture diversity, prevents bush encroachment and enhances the cycling of nutrients through the ecosystem (Goldman and Riosmena 2013). Nevertheless, there is consensus that pastoral mobility is beneficial for both pastoralists and the environment. However, rapid changes in this semi-arid and arid region arise from multiple factors, including rangeland fragmentation, violent conflicts, sedentarisation, and demographic drivers affect the effectiveness of the pastoralist mobility in times of drought.

While the colonial agenda was a sedentary life of pastoralists in Kenya within demarcated national boundaries, there are, however, new development with recognition of the internal movements as broadly protected by Kenya's bill of rights, particularly by the right to freedom of movement and choice of residence, which is also enshrined in regional and international human rights law (Schrepfer 2014). This right protects traditional nomadic movements, including from imposed sedentarisation or resettlement, although the law does provide limited protection to those who migrate as a form of adaptation. Cross-border migration, be it the traditional nomadic or adaptive, is a reality in Turkana and the other parts within the Horn of Africa. It is largely condoned, but there is an overwhelming need for regional or sub-regional facilitation of pastoral mobility as supported by the Africa Union Policy Framework for Pastoralism in Africa. Any such efforts should address the risks and challenges inherent in climate adaptation mobility and strengthen pastoral production system with the increasing climate stresses. The detailed description of mobility and limitations are sown in Table 2.3.

Table 2.3 Pastoralist mobility types in Turkana

Mobility	Character	Protection of mobility
Traditional nomadic	Internal	Right to freedom of movement and choice of residence as contained in Kenya's constitution, regional and international human rights law provides protection.
	Cross-border	Need for national and regional pastoral mobility policy in line with the AU Policy Framework for Pastoralism in Africa
Adaptive movement	Internal	Right to freedom of movement and choice of residence as contained in Kenya's constitution, regional and international human rights law provides limited protection to those who migrate as a form of adaptation. Need for migration management through strengthening of pastoral governance and in particular rangeland management.
	Cross-border	Need for national and regional pastoral mobility policy in line with the AU Policy Framework for Pastoralism in Africa.

Source: Adapted from Schrepfer (March 2014): On the margin: Kenya's pastoralists

Herd diversity: Besides mobility, rearing of mixed-species herds is another coping and risk management strategy employed by pastoral households in Turkana to optimize the use of heterogeneous ecosystem and meet different socio-economic obligations. Livestock species have different uses, feeding preferences, levels of physiological and behavioural adaptation, and tolerance to environmental stressors. Therefore, keeping a herd of mixed species is necessary for exploitation of the different ecological niches and the animals' complementary adaptabilities, as well as for meeting social and economic needs during drought conditions. Turkana pastoralist's stock their herd with a mixture of cattle, camels, donkey, goats, and sheep. The high population of sheep and goats (collectively referred to as shoats) is partly attributed to their drought tolerance and socio-cultural roles. In addition, shoats can be readily sold for cash to meet basic needs of pastoral households. Overall, livestock play a central role in Turkana. Their value goes beyond the production of meat; it is based on the full set of services they supply such as milk, meat, blood, hides, and their asset value as a form of savings, and their cultural symbolism.

Communal land ownership and rights to resources are central to pastoralism since it ensure that herd owners have access to water and pasture in different locations at different times of the year. In Turkana rangelands, no individual rights to pasture and water exist and crossing to other territories requires permission from the elders and the "*emuron*" who allocate resources use right to households. However, rights of access to pasture resources do not translate into utilization as some of the areas are not accessed due to threats of livestock raiding or the presence of livestock diseases. During dry seasons, the pastoralists are highly mobile with no fixed residence or regular pattern of movement. The households congregate together into several units called *adakar*. Movement and grazing management decisions are made at the communal levels (McCabe 2004). The arrangement is such that there is a wet and dry season grazing combined with the setting of specific dry season grazing reserves. Pertaining to access to water, individual rights are restricted to boreholes and wells dug and unrestricted to open sources such as flowing rivers, dams, and communal springs. In this way, pastoralists ensure that water and pastures resources can sustain them and are allowed to replenish. According to the recent household economic survey, up to 99% of households do not own individual land (Households Economic Assessment-HEA 2012), with less than 5% of the rural households with private land in urban centres, with allotment letters from the defunct County council of Turkana.

Whereas communal land ownership among the Turkana has been used as a drought adaptation and coping strategy, the inherent problem of common resource utilizations associated with non-excludability and non-rivalry regarding the use of resources becomes a challenge (Amisi 1997). For example, during severe droughts, the Pokot as well as the Samburu from the neighbouring counties in Kenya makes their way to the dry season grazing lands of Turkana. As competition in exploitation increases and resource bases dwindle, violent conflicts between the communities sometimes become inevitable (Schilling *et al.* 2012). Increasing privatization of communal land for other uses, such as cultivation and irrigation of pockets of dry season grazing corridors purportedly to spur economic growth, are likely to make herders more vulnerable to drought. Lease of productive grazing lands to private developers if implemented in violation of communal land rights, is likely to enhance vulnerability by pushing pastoralists further into a more fragile ecosystem.

Diversification: Livelihood diversification has been one of the main strategies for living with climate variability and other stressors in Turkana. Diversification of income sources is a core livelihood strategy of rural livelihoods systems in most developing countries (Little *et al.* 2001; McCabe *et al.* 2010). Watson and Binsbergen (2008), describe how Turkana pastoralists adapt a strategy of increased involvement in natural resource-based, non-pastoral income activities such as crop-farming. This is a response to both opportunities and constraints including the effects of stressors' such as drought. In this area livelihoods diversification are based on a variety of strategies, including livestock trading, fishing, sell of hide and skins, and cultivated crops; a variety of wage-earning occupations ranging from professional to manual labour; and entrepreneurial activities including shop keeping, craft production and sales, and transportation. Diversification activities have been found to have positive effects on vulnerability reduction in certain context, or at least prevent further deterioration due to weather events and climate, especially when supported by policy measures (Adger 2006; Stringer *et al.* 2009). However, some of these diversification strategies are often unavailable to the poorest, who lack the required resources or capitals to engage in during stresses or shocks.

Social protection schemes: Recent years have seen increasing interest approaches through different forms of social protection and insurance for the pastoralist groups in Turkana. Indeed, social protection is now seen as a 'basic service' alongside other human capital services such as health and education that helps people in chronic poverty reduce risk and protect assets during crises. Social protection covers a wide array of instruments designed to address the vulnerability of people's lives and livelihoods-through social insurance, offering protection against shock and stresses; through social assistance, offering cash payments and in kind transfers to protect the vulnerable against climate stresses and shocks; and through social inclusion efforts that enhance the capability of the marginalized to participate fully in economic and social life and to access social protection and other social services (High Level Panel of Experts-HLPE 2012). In Turkana, the governments, humanitarian and development partners have continued to invest on social protection scheme i.e. through the Hunger safety Net Programme (HSNP) to contribute towards economic growth of the vulnerable households. However, few studies exist on the effectiveness of social protection schemes for addressing incremental climatic change events, and the changing nature of climate risks as part of dynamic livelihood trajectories (Devereux *et al.* 2011).

Migration: Over the last decade, out migration to urban centres has been frequently used similarly as a strategy by the community to live with climate variability and other stressors in Turkana region. Information obtained from the review documents in the course of this study indicate that young men and women move temporarily from remote villages to Lodwar, Kakuma, Lokichar, Lokichoggio, Kitale and Nairobi, where conditions are favourable, or to locations which have good access essential services and facilities. Gender and demographic imbalances in population statistics also indicate that young adults, especially males, move from rural villages to urban settlements both within and outside the region. Parents also send children to boarding schools and some to town to work for upkeep and cash income to reduce the number of people they have to support with uncertain income.

2.5 Climate Change Policy and Implications for Adaptation

The policies, legal instruments and institutional frameworks related to climate change and environment have influence on communities' adaptation strategies. Adaptation is critical in dealing with the unavoidable impacts of climate variability and extreme weather events (Stringer et al 2009; Intergovernmental Panel on Climate Change IPCC 2012), yet the enactment of policy strategies to support adaptation at the national levels has been slow in most countries within Africa (Madzwamuse 2010). However, in Kenya there is widespread understanding and a strong political will that have acknowledged the impacts of climate change, due to the country's exposure to frequent and extreme climatic events such as drought events of 2004 to 2006, 2009 to 2009 and 2010 to 2011. This understanding has contributed to the development of a few polices for mainstreaming concerns regarding climate change into the overall strategies and planning processes.

Kenya developed a National Climate Change Response Strategy in 2010 which seeks to strengthen nationwide action towards adapting to, and mitigation against a changing climate by ensuring commitment and engagement of all stakeholders, whilst considering the vulnerable nature of the country's natural resources and society as a whole (Government of Kenya 2010).

The strategy provides a conducive and enabling policy, legal and institutional framework to combat climate change. It also provides a concerted action and resource mobilization plan to reduce and mitigate the impacts of climate change, and implementation timeframe at the national level. In addressing the threats posed by climate change as well as taking advantage of any opportunities that may arise, the strategy recommends eight objectives: (i) enhance understanding of the global climate change regime: the negotiation process, international agreements, policies and processes and most importantly the positions Kenya needs to take in order to maximize beneficial effects of climate change; (ii) assess the evidence and impacts of climate change in Kenya, iii) recommend robust adaptation and mitigation measures needed to minimize risks associated with climate change while maximizing opportunities, iv) enhance understanding of climate change and its impacts nationally and in local regions, v) recommend vulnerability assessment, impact monitoring and capacity building framework needs as a response to climate change, vi) recommend research and technological needs to respond to climate change impacts, and avenues for transferring existing technologies, vii) recommend a conducive and enabling policy, legal and institutional framework to combat climate change, and viii) provide a concerted action plan coupled with resource mobilization plan and robust monitoring and evaluation plan to combat climate change (Republic of Kenya 2010).

The national strategy and action plan demonstrates a positive step towards addressing mitigation and adaptation strategies in the country. Nonetheless, there is a need for more encompassing policies that address climate change adaptation and provide guidelines for their integration and mainstreaming into key sectors and institutions both at the national and county levels. However, the uncertainty of future climate variability and change calls into question the assumption that past and current strategies will be relevant under future conditions (Adger *et al.* 2005). For this reason, there is need to design the policy-making processes to be flexible in order to capture these uncertainty and future opportunities. At the national level though, the recognition of climate change is currently spread out into various sector laws and policies. These include the Forest Act, the Agricultural Act, the Energy Policy, the Forest Policy and the ASALs Policy (Madzwamuse 2010). However, these policy and legal instruments are weak and lacks explicit provisions for climate change adaptation. Not only is climate change not their focus, but they focus on natural resources and environmental management and do not consider the cross-cutting aspects of climate change in the local context. It can, however, be anticipated that once the draft Climate Change Bill (2012) is finalized it will sets out legal and institutional framework for ensuring mitigation and adaptation to climate change in Kenya. Furthermore, as is the case for countries in the Horn of Africa, a national policy vacuum leaves local county government with little or no effective guidance on how to deal with the many complex issues such as climate change in an integrated manner.

This review finding indicates recognition of climate change at the national level to be too vague and sketchy in policies. The reference to climate change adaptation in the context of building capacity as part of the environment sector under Kenya's vision 2030 is however, promising (Government of Kenya - GoK 2009). In the second Medium Term Plan (MTP 2013-2017) of vision 2030, the Kenya government has prioritized the management of climate induced disasters by strengthening people's resilience to drought and improving the monitoring of, and response to emerging frequent drought conditions (Republic of Kenya 2013). There is still a need to shift climate change away from solely highlighting environmental aspects to underscore development concerns at national, county and community levels in all the guiding policy documents with the focus on the vulnerable groups. The County Integrated Development Plans (CIDPs) for most of the ASALs counties including Turkana County on the other hand highlights climate change mitigation measures and adaptation strategies broadly in the local context and seems to outline the United Nations Framework Convention on Climate Change (UNFCCC) commitments including carrying out programmes aimed at reducing vulnerability to climate variability and drought episodes. In these CIDPs from the ASAL counties there is an appreciation of the impact of climate variability on lives and livelihood resources such as water, pasture and livestock resources. However, there is need to harmonize the proposed strategies and to strengthen the capacity of county level structures to promote policies that enhance adaptive capacity responses to climate change in the ASALs of Kenya.

It was observed interventions and polices that only aim to increase access to water resources, early warning systems, crop irrigation, markets and drought mitigation measures, on their own are not adequate for enhancing adaptive capacity of the vulnerable communities without paying attention to, and addressing, structural inequalities which underlie household socio-economic vulnerabilities in the arid and semi-arid environments (ASAL Policy 2012). For instance, pastoralists in Turkana of north-western Kenya have lost large tracts of communal grazing land through externally promoted crop irrigation schemes, oil exploration which took away the most important dry season grazing areas from the local communities. At the county level, there is opportunity to improve the way climate-related risks is dealt with, county governments need to systematically review current strategies and regulations to assess the synergies and gaps. This requires inter-sectoral and participative work with the actors concerned at the sub-county, county and national levels, as well as the establishment of related tracking and learning mechanisms. It is also yet to be seen how adaptation to changing policy environment amongst pastoralist communities may be as important as adapting to climate change to maintain livelihoods. There has also been a trend of customary formal and informal institutions giving way to village and district/county level governance structures and private household heads in regulating access to resources. All these changes pose a growing challenge to the use of some pastoral adaptation practices.

2.6 Conclusions

This chapter reviewed literature on pastoralist's vulnerability to climate variability and change in order to understand changing adaptation strategies for long-term climate resilience building in Turkana County, Kenya. The insights on past and present adaptation strategies used by the pastoralists' could be utilized in enhancing livelihood opportunities that could secure reasonable conditions for pastoral production systems in the changing climatic conditions. The following issues emerge from this literature review:

i) *Occurrence of extreme weather events:* Droughts are recurrent across Turkana, with many extreme and prolonged droughts in the last two decades (1990s and 2000s) than in the previous four decades (1950, 1960s, 1970s and 1980s). The effect of drought, low precipitation and high temperatures induced by climate change affect the availability of pasture and water resource for livestock. The frequencies of drought have necessitated the use of various complimentary livelihood activities that include; nomadic-pastoralism, transhumance, crop farming, fishing, nature-based enterprises i.e. charcoal production, wage labour and non-farm activities to address challenges caused by increased vulnerability to climate variability and change. It was noted that although these activities have helped the Turkana community maintain levels of consumption during period of stress, some of the activities have also had adverse ecological consequences with the impacts of climate variability and change. For example, with increasing number of households, engaging in charcoal making and fire wood harvesting as income generating activities is detrimental to the environment. Therefore, there is need for further research to better understand it's sustainably with the challenge of projected climate scenarios. Future research studies could also investigate the trade-offs to better understand the effects on other ecosystem services in Turkana.

ii) *Livelihood diversifications:* The literature review revealed that majority of pastoralists in Turkana survives not only through traditional mechanisms, but have also diversified their livelihood opportunities with majority depending on social protection scheme provided by government through their Hunger Safety net programme. Despite increase livelihood diversification activities, most of the Turkana do not display a total detachment from traditional nomadic pastoralism. The nomadic pastoralists in the far north and western part of the county were less likely to diversify their livelihoods. The fisher folk, transhumance and agro pastoral groups keep livestock more as an additional insurance against failure in other livelihood activities. However, it remains unclear how some of these indigenous adaptation mechanisms which are losing efficacy owing to socio-economic, political and environmental change will transform in relation to climate change in the long-term.

iii) *Integrated policy strategies:* From this review, rather than wholesome abandonment of pastoralism as livelihood strategy in Turkana, it's likely that a more coherent integration of policy strategies that enhances mobility and secure the communal land tenure in the ASALS will strengthening other support systems will ultimately improve pastoralism as a production system. This study suggest that the county governments need to systematically review current plan and strategies to assess the gaps on climate change adaptations at a more local level. The fragmentation and privatization of rangelands as well as conflicting institutional frameworks which threaten sustainability of pastoral mobility need to be addressed urgently in the policy documents. At the national level, there is need to address disparities in legislation of climate change policy in the draft Climate Change bill which if enacted will set legal and institutional framework for ensuring effective adaptation to climate change in Kenya.

2.7 Identified Gaps

There are also many attempts that have been made to understand how communities are adjusting their livelihoods strategies to cope with increasing climate variability and change in the Kenyan' rangelands (Notenbaert *et al.* 2007; Eriksen and Lind 2009). Studies by Notenbaert *et al* (2007) in Turkana reported that high levels of climate vulnerability are linked to factors such as a high reliance on natural resources, limited ability to adapt financially and institutionally, high poverty rates and a lack of safety nets. However, Eriksen and Linda (2009) on the other hand argued that people's adjustments to multiple shocks and changes, such as conflict and drought are intrinsically political processes that have uneven outcomes. Both studies concluded that strengthening local adaptive capacity is a critical component of adapting to climate variability. Research studies by Hassan and Nhemachenas (2008) reported that attention to determinants of households' vulnerability to climate variability and adaptation can contribute to socially and environmentally sustainable responses to extreme climate events in various production systems.

Similarly, literature review revealed that a number of climate variability and change impact studies have been conducted on specific sectors such as water resources, agriculture, health, and rangelands by using impact models and to a lesser extent socio-economic analyses (Smit and Wandel 2006; Eriksen and O'Brien 2007; Nassef *et al*. 2009). Global recommendation for Africa calls for an integrated assessment approach for vulnerability study, at a more local scale to account for the influence of local contexts (Intergovernmental Panel on Climate Change IPCC 2014). From the perspective of pastoral households, an understanding of vulnerability to climate variability and change is needed at the level that would specifically address specific geographic location and to tackle climate challenges with the precision that is necessary.

Insights from previous studies on climate variability impacts, vulnerability and adaptation processes are crucial in appreciating extent of the problem and need to design appropriate mitigation strategies at the regional, national and or local levels. However, much of the scientific knowledge for climate variability impacts on pastoralist fail to provide critical insights on the interaction between the climate variable and human factors at the micro or household level. As a result, the current study provides evidence for policy decisions with regards to the influence of climate variability and change on households' vulnerability and their possibilities to cope with – and recover from climate shocks as a pre-requisite for enhancing resilience in the ASALs.

CHAPTER THREE

STUDY AREA AND METHODOLOGY

3.1 Study Area

3.1.1. Demographic characteristics

Turkana County is one of the largest counties in Kenya, and covers over 68,680.3 Km² with an estimated human population of about 1,036,586 persons in 2012 based on population census projections (Table 3.1). The region is considered one of the poorest counties with 87.5% of its population living below the absolute poverty line (Kenya National Bureau of Statistics-KNBS 2013). The County is inhabited by the Turkana ethnic community whose major livelihood activity is pastoralism (Watson and van Binsbergen 2008).The livestock species kept include camels, cattle, sheep, goats and donkey, and have different forage and water requirements and variable levels of resilience to drought. However, famine, malnutrition, diseases outbreaks, droughts, and violent conflict are common hazards in the area. In most instances, the hazards experienced impacts on the people and are exacerbated by poor infrastructure and low access to basic services, in addition to other underlying causes of poverty that are experienced in northern Kenya (Notenbaert *et al.* 2013). The majority of Turkana community are known to be highly mobile with no fixed residence and have regular pattern of movement that often get disrupted by conflicts and diseases outbreaks (Schilling *et al.* 2012). Their grazing lands extend to the southern borders towards West Pokot County, occupied by the Pokot pastoralists, with whom the Turkana herders share resource use networks, as well as livestock raids and conflicts. In the study area because of aridity, managing frequent climate fluctuations is critical in sustaining their livelihoods (Coppock *et al.* 1986).

In the recent years rangeland degradation has become a common phenomenon, thereby threatening the survival of Turkana community who has long depended on this rangeland resource for their survival (Kigomo and Muturi 2013). The main factors associated with increasing rangeland degradation in the area include over-exploitation of resources due to localized increase in human and livestock populations, changing land use patterns, sedenterisation of the pastoralist, privatization of the communal land tenure, insufficient and unreliable rainfall and poverty caused by changing climatic conditions.

Table 3.1 Population projections by age groups

Age group	2009(Census)			2012 (Projections)			2015 (Projections)			2017 (Projections)		
	Male	**Female**	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**
0-4	57,530	54,049	111,579	69,716	65,497	135,213	84,483	79,371	163,854	96,027	90,216	186,243
5-9	71,898	66,175	138,073	87,127	80,192	167,319	105,582	97,178	202,760	120,009	110,457	230,466
10-14	77,156	66,405	143,561	93,499	80,471	173,970	113,303	97,516	210,819	128,786	110,841	239,626
15-19	66,881	52,307	119,188	81,047	63,386	144,434	98,215	76,813	175,027	111,635	87,309	198,944
20-24	43,110	37,149	80,259	52,241	45,018	97,259	63,307	54,553	117,860	71,957	62,008	133,965
25-29	30,703	30,850	61,553	37,206	37,385	74,591	45,087	45,303	90,390	51,248	51,494	102,742
30-34	21,742	24,234	45,976	26,347	29,367	55,714	31,928	35,588	67,516	36,291	40,450	76,741
35-39	17,473	21,423	38,896	21,174	25,961	47,135	25,659	31,460	57,119	29,165	35,758	64,924
40-44	14,240	15,130	29,370	17,256	18,335	35,591	20,911	22,218	43,130	23,769	25,254	49,023
45-49	11,584	11,644	23,228	14,038	14,110	28,148	17,011	17,099	34,110	19,336	19,436	38,771
50-54	9,211	9,137	18,348	11,162	11,072	22,234	13,526	13,418	26,944	15,375	15,251	30,626
55-59	6,892	6,823	13,715	8,352	8,268	16,620	10,121	10,020	20,140	11,504	11,389	22,893
60-64	6,010	5,436	11,446	7,283	6,587	13,870	8,826	7,983	16,808	10,032	9,074	19,105
65-69	3,419	3,129	6,548	4,143	3,792	7,935	5,021	4,595	9,616	5,707	5,223	10,930
70-74	2,771	2,349	5,120	3,358	2,847	6,204	4,069	3,450	7,519	4,625	3,921	8,546
75-79	1,470	1,390	2,860	1,781	1,684	3,466	2,159	2,041	4,200	2,454	2,320	4,774
80+	2,741	2,530	5,271	3,322	3,066	6,387	4,025	3,715	7,740	4,575	4,223	8,798
age NS	238	170	408	288	206	494	350	250	599	397	284	681
TOTAL	**445,069**	**410,330**	**855,399**	**539,342**	**497,244**	**1,036,586**	**653,583**	**602,569**	**1,256,152**	**742,891**	**684,906**	**1,427,797**

Source: Turkana County integrated development plan- CIDP 2013-2017.

3.1.2. Location and geo-physical characteristics

The study was conducted in Turkana County, in the vast northern Kenya. The county lies between longitude 34º 30' and 36º 40'East and between latitude 10º 30' and 5º 30' North (Figure 3.1). Turkana County shares international borders with South Sudan and Ethiopia in its northern part and Uganda in the North-west. The area is hot and dry throughout most of the year and is characterized by seasonal and bimodal rainfall distribution with high temporal and spatial variability between seasons and years. The region is considered to have bimodal rains. The long rains normally occur between March, April and May (MAM), and the short rains between October, November and November (OND). The rainfall ranges between 120mm and 500mm per year; with the western parts with higher elevation receiving more rainfall than the lowlands in Turkana County. Rainfall variability is extreme both in space and time, with rainfall patterns highly skewed in distribution (Figure 3.2). The intra-year coefficient of variation is more than 50% throughout the county, with peaks of 95% and more in the driest northern areas. The northern part towards Southern Sudan and Ethiopia are more arid than the western areas towards Uganda which is semi-arid. In Turkana because of aridity, managing short-term climatic fluctuations as well as adapting to long-term changes is critical in sustaining livelihoods. As common with other tropical region within the Horn of Africa, Turkana area experiences high temperatures throughout the year and inter-annual temperature range between minimum 23°C, and maximum 38°C, with a mean of 30°C.

The vegetation is widely varied and ranges from patchy annual grassland and herbaceous plants to riverine woody trees species, although most parts of the district have dwarf shrubs and bushed species (Coughenour and Ellis 1993). The woody vegetation species include *Acacia mellifera, Acacia tortilis, Balanites aegyptiaca, Zizyphus mauritiana, Cordia sinensis* and *Dobera glabra.* The density of plants such as *Acacia reficiens* and *A. Mellifera* increases as one move away from the settlement areas, especially in poor range conditions where soil moisture is more limited (Kariuki et al. 2008). The introduced *Prosopis juliflora* tree species has increasingly become an important invader, especially along the riverine, road sides and human settlements. Due to severe degradation, herbaceous vegetation species, especially grasses, are almost non-existent, except along the conflict prone border regions of Turkana and the Karamojong of Uganda. Other fast growing species introduced on a small scale as result of firewood shortage and demand for woody plants include *Acacia aneura, Atriplex aurionformis, Azandrachta indica, Parkinsonia aculeate* and *Acacia horosericea* (Kariuki *et al.* 2008). *Acacia reficiens, Abutilon frutico-sum* and *Cadaba rotundifolia* are mostly harvested for the construction of livestock enclosures and houses. Most parts of Turkana's rangelands are heavily overgrazed with the greatest threat from encroachment by the invasive *P. juliflora*. The soils are predominantly sandy but occasionally intercepted by patches of black cotton soils (Van Bremen and Kinyanjui 1992).

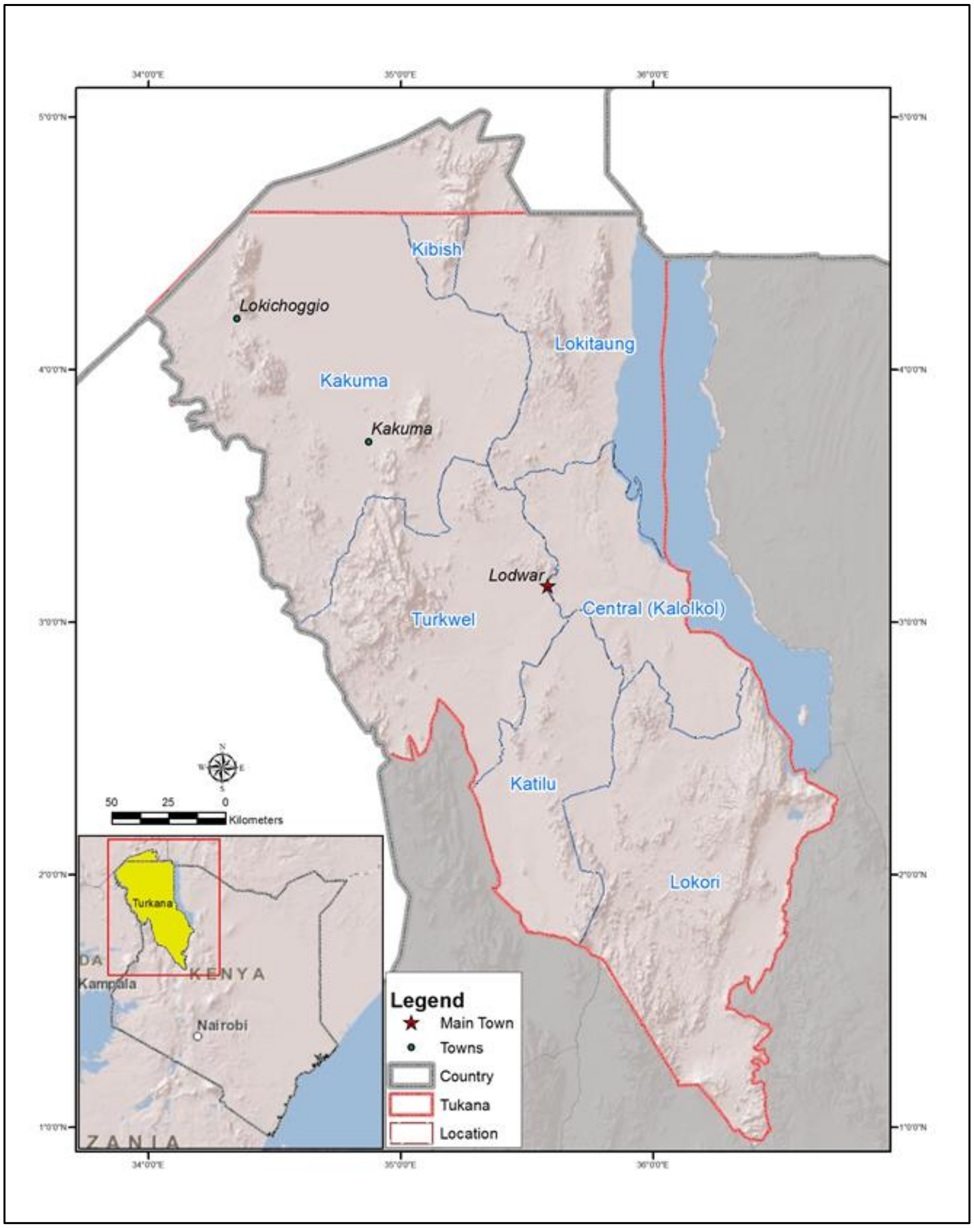


Figure 3.1 Location of the study area in Turkana County, Kenya

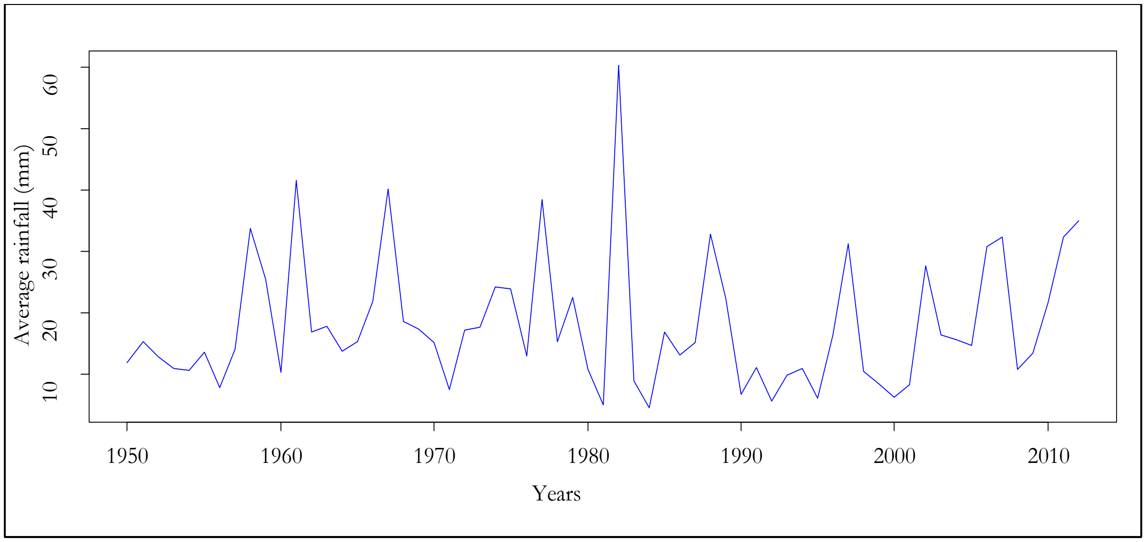


Figure 3.2 Mean annual rainfall trend from 1950 to 2012 for Lodwar, Turkana

3.2 Methodology

3.2.1 Research design

This study used a multistage sampling technique. First, Turkana County was purposively sampled based on the geographical location, dominant livelihood activity and proneness to drought events. Afterward, the divisions within the county was listed and categorised on the basis of the various livelihood zones, land-use systems activities, accessibility and the extent to which they were perceived to be prone to extreme climate events. This was then followed by random selection of nine study locations from Lokichoggio, Kakuma and Oropoi. After random selection of the study locations, the total number of households was obtained from the Kenya National Bureau of Statistics records for the area. The sample size in each of the location was systematic selected using sample size formula by Krejcie and Morgan (1970), see the equation. A random start was used in choosing the first household to be interviewed. For the selected households whose heads was absent, next household was chosen and interviewed, a total of 302 households were interviewed from Lokichoggio, Kakuma and Oropoi of Turkana County.

$$S = X^2NP\ 1 - P\quad \div d^2\ N - 1\ \ + N^2P\ 1 - P$$

$S =$ required sample size

$X^2 =$ The table value of Chi-square for 1 degree freedom at desired confidence level (3.841)

N = Population size

P = The population proportion (assumed to be 0.50 since this would provide maximum sample size).

d = the degree of accuracy expresses as proportion (0.05).

d = the degree of accuracy expressed as a proportion (0.05).

The data on interview questionnaire was collected from 302 households for a period of two months from June to July 2012. Data were collected on socio-demographic, economic and biophysical variables of the households. Examples of the data collected were household characteristics, production systems, livestock production, climate change information, climate impacts, adaptation strategies, other livelihood strategies, farm labour, social networks and remittances. The collected data were coded and thereafter analysed using STATA software (version 9.0) from StataCorp LP (StataCorp 2013) for descriptive statistics and regression analysis to achieve the objectives of this study.

To complement the household questionnaire data, 34 individual from various organizations were interviewed a key informants. Ten focus group discussions (FGDs) were also conducted separately with a gender parity (of five men and five women) from the sampled villages to cross-check and validate answers from household respondents. In addition, *in-situ* rainfall and temperature time-series data were obtained from the Kenya Meteorological Services (KMS), and National Drought Management Authority (National Drought Management Authority NDMA) in Nairobi and Lodwar respectively. The time series data on climate parameter were used to calculate rainfall (1950-2012) and temperatures (1979-2012) trend patterns. Normalized Difference Vegetation Index (NDVI) satellite dataset was retrieved from International Livestock Research Institute (ILRI) database in Nairobi, Kenya

3.2.2 Data collection process

3.2.2.1 Reconnaissance

Initial reconnaissance survey of the study area was conducted prior to commencement of the actual study. The objective was to meet relevant stakeholders and to introduce the study objectives and discuss its relevance to decision making processes. The stakeholders meet during the introductory meeting were local administrators, National Drought Management Authority (NDMA) drought early warning monitors, extension officers and local elders. The pre-study session was very instrumental as it helped in cementing local community trust as well providing more insights into areas that the stakeholders prioritized for the study assessment. Besides, this enabled a better understanding of the peculiarities of the study area, the size of the sample frame that was considered and identification of local enumerator for the household's interview.

3.2.2.2 Training of local field assistants

Field assistants were used to have a participatory process where the locals were involved for ownership and participation. In total, eight (8) field assistant were recruited locally with assistance of NDMA based on their previous research experiences, knowledge of local language and qualifications. The training was conducted for three days and piloted before the onset of the households' interviews. The training objective was to minimize biases and errors in data collection, and to familiarize the field assistants with the objectives of the research questions, interactive ways to ask question and tools to be used.

3.2.2.3 Questionnaire pre-testing

A pilot test-run was conducted with local enumerators prior to the main survey, and the final questions were amended accordingly. The pre-test questionnaire was used on 16 households around Lokichoggio. The questionnaire used for pre-test was excluded from the final data entry and analysis. The piloting was done to check the suitability of the tools and also whether the field assistants could pose the question without difficulty.

3.3 Data Collection

3.3.1 Questionnaires interviews

A semi-structured questionnaire with open-ended, multiple-response and dichotomous questions was used to collect data. Information on various aspects was obtained through the administration of a questionnaire on individual households head. A questionnaire interviews collected data on various socio-demographic and economic variables of households, livestock production system, drought impacts, aspects on households' adaptation and coping strategies under investigation (Annex 1). To avoid misinterpretation, the household interviews' were conducted in the local language by the local field assistants.

As a means of data collection technique, questionnaire interview allows for any complex questions to be explained, if necessary, to the interviewee. It has more scope to ask open-ended questions since respondents do not have to write in their answer and the interviewer can pick up on non-verbal clues that indicate what is relevant to the interviewees and how they are responding to different questions.

In addition, secondary data were obtained from existing literature including published reports from relevant sources, journal papers and on line resources. The information generated through household questionnaire interviews was further validated through FGDs, informal interviews and general observations.

3.3.2 Focus group discussions and key informant interviews

Ten focus group discussions (FGDs) were conducted separately with a gender parity (of five men and five women) from the sampled villages to cross-check and validate answers from household respondents. The participants in FGD were selected based on gender with the help of the local leaders. Representatives from various interested groups that have been working on drought management with Humanitarian agencies and development organizations were selected to be part of the groups. There was no doubt that FGDs created opportunity for interaction between community members and lead to verbal expression and opinions about the discussion on broadly climate change. The discussions held with community different groups aimed at capturing the local knowledge on climate variability and its impacts on local communities, vulnerability, and adaptation and coping options to extreme climate events

Further discussions were held people considered to be key informant individually between June 2012 and August 2013. A total of 34 individuals from local organizations, peace committee, water and pasture committee, local chiefs, village elders and drought monitors, community-based animal health workers, and opinion leaders were interviewed to solicit more information and knowledge on climatic variability and change in Turkana.

3.3.3 Rainfall and temperature time-series data

The long-term time-series data were obtained from the Kenya Meteorological Services (KMS), and National Drought Management Authority (National Drought Management Authority NDMA) in Nairobi and Lodwar. The time series data on climate parameter were used to calculate rainfall (1950-2012) and temperatures (1979-2012) trend patterns. The seasonal, annual and means for rainfall and temperature were computed to achieve the objectives of the study.

3.3.4 Normalized difference vegetation index (NDVI)

The Normalized Difference Vegetation Index (NDVI) derived from the AVHRR satellite, with dataset for the period 1998-2011 and reasonably spatial pixel resolution of 8 by 8 km provides an excellent tool for the analysis of vegetation anomalies within the three spatial domains namely Lokichoggio, Kakuma and Oropoi used in this study. AVHRR 10 day’s composite of surface reflectance for both minimum and maximum NDVI were obtained from International Livestock Research Center (ILRI) database in Nairobi, Kenya for this study.

The monthly NDVI values were then averaged for each of the three administrative units covered in Turkana. Since NDVI is thought to be closely related to rainfall seasonality (Anyamba and Tucker 2005), the analyses were confined primarily to the ‘long’ and ‘short’ rainy seasons, which account for most of the rainfall received in a year. The months of March, April and May, hereafter referred to as MAM long rains growing period, while October, November through

December (OND) represent the short rains growing period. The long-term NDVI climatology (1998-2011) was created by averaging data for all cloud-free pixels for MAM and OND for the same period. NDVI data are separately normalized in order to give the same weight to all the grid-points and to both NDVI and rainfall, which are put together into a single matrix. The year to year variability in the NDVI patterns was examined by calculating yearly MAM and OND anomalies as follows:

$$NDVI\sigma = \frac{NDVI\alpha}{NDVI\mu - 1} 100 \quad \ldots\ldots\ldots\ldots (1)$$

where: NDVIσ are the respective MAM and OND anomalies, NDVIα are individual seasonal MAM and OND means and NDVIμ is the long-term MAM and OND mean. The NDVI is unit-less, with values ranging from –1 to +1. Healthy green vegetation normally has the highest positive values while surfaces without vegetation, such as bare soil, water, snow, ice or clouds usually have low NDVI values that are near zero or slightly negative.

3.3.5 Vegetation species

A systematic sampling was undertaken for ground truthing for discussing vegetation species richness and abundance in relation to satellite NDVI data observed. Plot transect was used for vegetation sampling across the sampled locations in Turkana. Three 6-km long transects were mapped out along the road from Lokichoggio, Oropoi to Kakuma. In each of transect, six perpendicular lines sub-transects measuring 100 m each were cited at regular intervals of 1 Km along the main transect. On each sub-transect, two main plots each measuring 10 m by 10 m were marked out on both sides. A total of 28 plots were established. On each sample plot data on species richness, abundance, and cover for trees, shrubs and herbs was collected.

3.4 Data Analysis

Analysis of data combined both qualitative and quantitative approaches. The data obtained were analysed using multiple statistical techniques described under each study chapter in this study. General, descriptive and regression models were used to ascertain various aspects of household characteristics, production systems, income sources, and adaptation strategies and their influence on household vulnerability to climate change and variability.

The collected data were coded and thereafter analysed using STATA software (version 9.0) from StataCorp LP (StataCorp 2013) for socio-economic characteristics of respondents and related variables to achieve the objectives of this study.

The NDVI data were geo-registered and inverse weighted (Kriging) used for predictions interpolated with the coordinates in order to generate seasonal maps. Repeated measures of ANOVA (SYSTAT Inc. 1992), F-test was used to compare the effects of time from years (1998-2011) on total vegetative cover for each study location. The year was considered fixed effects for analysis of variance. Statistical tests were considered significant at $P<0.05$.

CHAPTER FOUR

TREND ANALYSIS OF RAINFALL AND TEMPERATURE VARIABILITY IN ARID ENVIRONMENT OF TURKANA, KENYA

Abstract

Scrutiny of seasonal, monthly and inter-annual temporal variability of rainfall and temperature is vital in assessing climate-induced changes, and to suggest adequate future adaptation strategies for vulnerable communities in arid environments. This study focused on temporal trends analysis of *in-situ* rainfall and temperature records for Lodwar in Turkana County, Kenya using non-parametric Mann-Kendall test statistic. The rainfall datasets used were for the period 1950-2012, and temperature period 1979-2012. The results revealed high inter-annual rainfall variability (CV >90.0%), with non-significant ($p<0.05$) decrease in March- May (MAM) rainfall, and increase in October - December (OND) rains for the period 1950-2012. The study area recorded relatively low mean annual rainfall for the 'long rains' (30.7mm) and 'short rains' (17.2mm) over the same period. A rise in minimum (0.2°C), maximum (0.1°C) and mean (0.13°C) temperature occurred between 1979 and 2012. The December – February (DJF) season recorded the highest mean temperature (36.27 °C), while OND season had the lowest mean minimum temperature of 20.87°C over the past 30 years in Lodwar. There were more years with below normal rainfall from 1971 to 1999 than between 1961 and 1989, leading to the observed recurrence of multi-year drought events. Overall, the findings are in line with recent trends of global warming in the region as reported by the latest Intergovernmental Panel on Climate Change (IPCC 2014) report.

Keywords: Climate variables, Kenya, Mann-Kendall, non-parametric tests, trend analysis

4.1 Introduction

Rainfall variability and reliability have recently received considerable attention by the scientific community at different scales in the ongoing debates on climate change. In fact, climate projections suggest that variability is likely to increase in the future and extreme weather events might become more frequent in sub-Saharan Africa (Hulme *et al.* 2001; Cooper *et al.* 2008; Intergovernmental Panel on Climate Change IPCC 2012; Omondi *et al.* 2013). However, the reality is that the effects, risks and uncertainty with the science around the subject of climate change and projections are daunting, challenging and complex to understand at different levels. This is perhaps true that the subject of climate change is one of the most controversial in the entire science of meteorology and climatology at present (Kalumba *et al.* 2013). Understanding dimensions of monthly, annual, seasonal rainfall and temperature therefore has become an important part of research studies helping to clarify climate change discourses and its effects on the natural behaviour of ecosystems and arid systems. In the recent years, time-series studies of rainfall and temperature patterns and environments have been carried out at various spatial (e.g. regional, national) scales using various statistical procedures (Hamed 2008; Collins 2011; Barbar and Ramesh 2013; Wagesho *et al.* 2013). Yet, very few have considered both in-situ long rainfall and temperature data as climate parameters in their analysis using non-parametric approaches such as Mann-Kendall test (Mann 1945; Kendall 1975) to analyse trends at spatial and temporal (e.g. annual, seasonal, monthly) scales. Relevant reviews on trend analysis in rainfall using Mann-Kendall statistical test in the region include Mondal *et al.* (2012), and Wagesho *et al.* (2013). Nonetheless, information on trends of rainfall and temperature in either temporal or spatial scale leads to a better understanding of the challenges associated with effects of extreme climate events especially in sub-Saharan Africa where majority of the people reside in highly variable arid and semi-arid environments.

Previous studies on climate trend (King'uyu *et al.* 2000; Nicholson 2000; Hulme *et al.* 2001; Schreck and Semazzi, 2004; Mwangi and Desanker 2007; Moyo *et al.* 2012; Wagesho *et al.* 2013) across Eastern Africa region revealed that there has been high inter-annual rainfall and temperature variability in the region, especially within the arid and semi-arid environments. Further, a range of climate models suggest median temperature increases between 3°C and 4°C in Africa by end of the 21st Century, roughly 1.5 times the global mean response (Intergovernmental Panel on Climate Change IPCC 2007; Bryan *et al.* 2013). In Kenya, global circulation models predict that, by the year 2100, climate change will increase temperatures by about 4°C and cause variability of rainfall by up to 20% (WWF 2006; Kabubo-Mariara 2008). From the available literature, the daily temperature observations already show significantly increasing trends in the frequency of warm days, and larger increasing trends in the frequency of warm nights (King'uyu *et al.* 2000; Omondi *et al.* 2014). However, WWF (2006) reported that the average number of warm days per year in Kenya have increased by 57% between 1960 and 2003. The rate of increase is seen mostly in March, April and May when the average number of hot days has increased significantly by 5.8 days per month, thus an additional 18.8 per cent of March, April and May days over this period. More broadly, other studies suggest that in the predominantly arid and semi-arid environments, there is significant rainfall variation from year to year and these trends may continue with the wet season increasing and at the same time offsetting decreases in the drier months (Nyong and Niang-Diop 2006). Similarly, the seasonality in rainfall and temperature at inter-annual, or monthly time scale makes the climatic variation understanding within a wider geographical scale even more complex. For instance, studies of extreme rainfall trends show increased frequency of more intense rainfall events in many parts of Kenya whereas the number of rainy days and total annual precipitation decreased, with considerable reduction in the length of the growing season in the arid and semi-arid environments (Galvin *et al.* 2001). Kenya's intra-seasonal component is intrinsically unpredictable (Moron *et al.* 2013). In contrast, Thornton *et al.* (2002) observed that other parts of Kenya including parts of the southern rangelands may become wetter, with increases in the length of the growing seasons. Comparably, in the neighbouring Southern Ethiopia, Deressa *et al.* (2011) observed a complex rainfall and temperature trend patterns, with average minimum and maximum temperature increase of about 0.25 and 0.1, respectively, over the past decade, whereas rainfall patterns was characterized by unpredictable trends for the past 50 years. Angassa and Gobu (2007) on the other hand revealed decreasing trends in the mean annual rainfall analysis at Borana in the southern Ethiopia. In contrast, Seleshi and Zanke (2004) reported that there was no recent trend in rainfall over the north-western and southern Ethiopia for the period 1965-2002. The variability in rainfall and temperature at different scales is therefore, seen as normal occurrence in the arid climates, with most predictions reporting an increasing temperature in the region including Kenya (Christensen and Hewitson 2007; Herrero *et al.* 2010; Vizy *et al.* 2012; Cook *et al.* 2013).

Hitherto, limited scientific studies have focused on spatial and temporal analysis of climatic parameters at micro-scale in the arid and semi-arid environment of northern Kenya. There are few detailed work on rainfall and temperature trends using observed climate records. Yet, this region in the recent past has experienced extreme weather events and micro climatic variability reported to have had huge influence on ecosystem dynamics and human welfare especially in this environments (Conway *et al.* 2005; Herrero *et al.* 2010). Understanding climate trends and magnitude is critical to mitigate the adverse impacts of climate change and variability, and would guide communities to make strategic, long-term decisions that affect their future well-being. Therefore by studying the trends and changes in the rainfall and temperature with a simple yet direct approach, the results hope to show how policymakers and the communities can better prepare for natural extremes and reduce the loss of life and property. The objective of this study therefore was designed to analyse rainfall and temperature trends and seasonal changes spanning the period between 1950-2012 and 1979-2012 respectively, using non-parametric Mann-Kendal statistical test approach. This study analysed rainfall and temperature trends at monthly, seasonal and annual scales using observed data at Lodwar weather station for the basis of modelling future climate scenarios.

4.2 Material and Methods

4.2.1 Study area

The detailed description of the study area and the research design is found in Chapter Three of the Thesis.

4.2.2 Rainfall and temperature data

The rainfall and temperature data for Lodwar weather station managed by the Kenya Meteorological Services - KMS were used to evaluate trends and variability of Turkana County, Kenya. The choice of Lodwar weather station was informed by availability of long-term rainfall data. The data records at Lodwar weather station are a fair representation of the entire Turkana homogeneous climatological zone identified by Indeje *et al.* (2000). The datasets obtained include monthly rainfall averages together with minimum and maximum temperatures. There were no missing data records, so the datasets were generally considered to be comprehensive enough for the estimation of rainfall and temperature related variables.

Delineation of seasonality for the periods was based on summing the corresponding monthly rainfall and temperature averages recorded during 1950-2012 and 1979-2012 respectively in Lodwar. Subsequently, each calendar year was divided into four climatic seasons based on northern Kenya's weather patterns namely; long rains March-May (MAM), short rains October-December (OND), dry spell December-February (DJF) and another dry June-August (JJA) seasons. Because Turkana being part of northern Kenya lies astride the equator, experiences two rainy seasons occurring when the Inter-tropical convergence zone (ITCZ) traverses the region in its southward and northward migrations. A longer rainy season starts around March through to May, with the peak centered on April. The shorter rainy season runs from October and December (OND). Similar monthly clustering of season used in this study has been widely adopted by other previous studies across the region (Collins 2000; Camberlin and Philippon 2002; Omondi *et al.* 2013; Kansiime *et al* 2013; Nicholson 2014). For this study, mean rainfall values were calculated based on monthly, seasonal, yearly and 30 years climatological periods (i.e. with first climatological periods 1961-1990, and second climatological period 1971-2000, and temperature on 30 years (first climatological period 1981-2010) classifications. The climatological periods were selected based on recommendation from The World Meteorological Organization (WMO) guidelines on climate trend analysis (Klein *et al.* 2009). The averages for each month and year provided values for statistical analysis.

4.2.3 Analytical methods

In this study, Mann-Kendall statistical test method was applied to the monthly, annual and seasonal temporally distributed rainfall and temperature data trends at 1 and 5% level of significance. The Mann-Kendall test method does not require the data to be normally distributed. Similarly, the test is a non-parametric statistical procedure that is well suited for analysing trends in data over time, and has low sensitivity to abrupt breaks due to inhomogeneous time series. A non-parametric test is preferred over the parametric in view of its ability for analysis of data that is not normally distributed (Yue and Wang 2004; Hamed 2008; Mondal *et al.* 2012; Barbar and Ramesh 2013). The Mann-Kendall test does not require any assumptions as to the statistical distribution of the data, for example normal, lognormal, etc., and it can also be used with data sets which include irregular sampling intervals and missing data (Kendall 1975). Mann-Kendall (MK) test was formulated by Mann (1945) as non-parametric test for trend detection, and the test statistic distribution was for testing non-linear trend and turning point (Gilbert 1987; Kendall 1975). Studies (Yue and Wang 2004; Karmeshu 2012; Barbar and Ramesh 2013) show that trend detection in a series is largely affected by the presence of a positive or negative autocorrelation.

The Mann-Kendall Statistic (S) measures the trend in the data. Positive (+) values indicate an increase in constituent concentrations over time, whereas negative (-) values indicate a decrease in constituent concentrations over time. The strength of the trend is proportional to the magnitude of the Mann-Kendall Statistic (where large magnitudes indicate a strong trend). However, the data used for the Mann-Kendall analysis should be in time sequential order. The MK statistic (S) is defined as the sum of the number of positive differences minus the number of negative differences (Sneyers 1990) as follows:

$$\mathrm{S} = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \mathrm{sign}\ (\mathrm{xj} - \mathrm{xk}) \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .. (1)$$

Sign $(x_j - x_k)$ is an indicator function that results in the values -1, 0, or 1 according to the sign of $x_j - x_k$ where j>k, assuming that $(x_j - x_k) = \theta,$ the value sign θ is computed as follows:

$$\text{Sign}\ \theta = \begin{cases} 1 & \text{if} \quad \theta > 0 \\ 0 & \text{if} \quad \theta = 0 \\ -1 & \text{if} \quad \theta < 0 \end{cases}$$

This statistic represents the number of positive differences minus the number of negative differences for all the differences considered. To deal with the non-monotonic character of trends in the data, the Kendall (1975) was used to estimate a normal-approximation test for large data sets with more than 10 values; the test is conducted using a normal distribution (Helsel and Frans 2006) with the mean and the variance as follows:

- Calculate S as described in equation 1
- The variance of S is calculated, VAR(S) by the following equation:

$$VAR(S) = \frac{1}{18} = n(n-1)(2n+5) - \quad t(t-1)(2t+5) \quad \ldots\ldots\ldots\ldots\ldots (2)$$

where *n* is the length of data set (zero difference between compared values), and *t* the number of data value in a group of determination. The standard normal deviate (*Z*-statistics) is computed as (Hirsch *et al.* 1993) follows:

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} & \text{if } S < 0 \end{cases} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (3)$$

To compute the probability associated with the normalized test statistics. The probability density function for a normal distribution is described by the following equation:

$$f(z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{z^2}{2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

In this analysis, the null hypothesis was tested at 95% confidence level. The trend is decreasing if Z is negative and the computed probability is greater than the level of significance. Similarly, the trend is increasing if the Z is positive and the computed probability is greater than the level of significance. However, if the computed probability is less than the level of significance, there is no trend detected. To further reflect the comparisons, the Pearson's correlation coefficient was used to calculate and detect the seasonal association between precipitation and temperature considered in this study.

4.3 Results and Discussion

4.3.1 Monthly and seasonal rainfall trends

The maximum monthly rainfall (197.7 mm) was observed in 1961 during the month of December. The findings revealed that nearly all the months showed below normal mean rainfall for the period 1950-2012, except for March, May, August, Sept, Oct, Nov and Dec. Table 4.1 summarize Mann-Kendall (Z) statistical tests for the monthly rainfall at 95% confidence level. The results showed that December (0.04) depicted positive increasing trends while the months of January (-0.06), February (-0.01), April (-0.11) and July (-0.05) showed negative trends while the other months showed increasing and decreasing scenarios which were not statistically significant (at $\alpha = 0.05$) for the period 1950-2012. In addition, the rainfall data were split in two discrete parts to ascertain the temporal trends. First climatological period 1961-1990, the monthly results revealed decreasing trends for Jan, Feb, March, April, July August, October and November. For second climatological period 1971-2000, the rainfall had a mixture of increasing and decreasing trends, but the trend values were equally not statistically significant for all the months.

Table 4.1 Mann-Kendall derived trend values for rainfall estimates for Lodwar, Turkana

Variable	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Period
Monthly Rainfall trend (MK* Test stat)	-0.06	-0.10	0.04	-0.11	0.11	-0.02	-0.05	0.06	0.07	0.14	0.06	0.04	1950-2012
Monthly Rainfall trend –First climatology (MK Test stat)	-0.06	-0.07	-0.01	-0.1	0.08	0.05	-0.06	-0.12	0.23	-0.21	-0.15	0.15	1961-1990
Monthly Rainfall trend -Second climatology (MK Test stat)	-0.16	-0.02	0.08	-0.12	-0.13	-0.03	-0.11	0.01	-0.28	0.04	0.01	0.16	1971-2000

MK* - Mann–Kendall test with positive (+) for increasing and negative (−) for decreasing

The positive trends were observed in March, August, Oct, Nov and Dec while the other months had negative trends. This result suggests a seasonal movement toward concentrated rainfall in OND during the short rainy season. However, it should be noted that these trends are non-significant. Previous studies (Camberlin and Philippon 2002) show that most part of the region receives significant amount of rainfall during the months of March-May. Mutai and Ward (2000) observed that the rainfall trends in East Africa region are higher during the long rains in MAM when compared to the OND season. Nonetheless, it was also apparent from the findings that there is no clear rainfall trend observed overtime in Turkana (Figure 4.1), suggesting that the monthly rainfall trends were likely to be unpredictable. Similar observations were made by Amissah-Arthur *et al.* (2002) when they characterized effects of *El Nino* events on rainfall trends in Kenya.

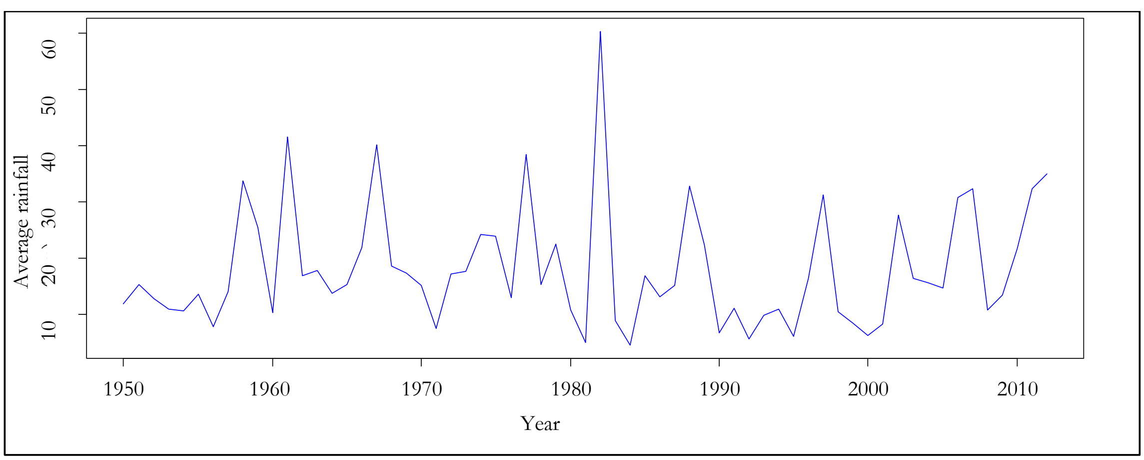


Figure 4.1 Monthly average rainfall trends from 1950 to 2012 for Lodwar, Turkana

This seasonal results show that rainfall is not only low but highly variable and unpredictable over time in the study area. The Mann-Kendall test statistics for trends performed on a seasonal scale to examine if there are patterns in the data at this scale showed varied results. Figure 4.2 illustrates seasonal rainfall trend patterns for the period 1950-2012. The OND season recorded the highest rainfall of 197.7 mm in December 1961, while DJF recorded 111.2 mm in 1958 January and JJA recorded 171.4 mm in August 1982. Considering the entire MAM dataset, April 1967 received the highest amount of rainfall (185.7mm) and lower amounts observed in May, June, July with some of these months recording zero millimetres of rainfall. Turkana rainfall patterns are bimodal and occur in March to May (MAM) commonly referred as the long rainy seasons with peaks rains in end of March and April. The short rains are experienced between October and December (OND) with the peak in November. The rest of the calendar years are known to be dry seasons except June and July which occasionally experiences slight precipitations. The seasons for arid and semi-arid environment in Kenya are well differentiated and the details can be found in Jaetzol *et al.* (2005).

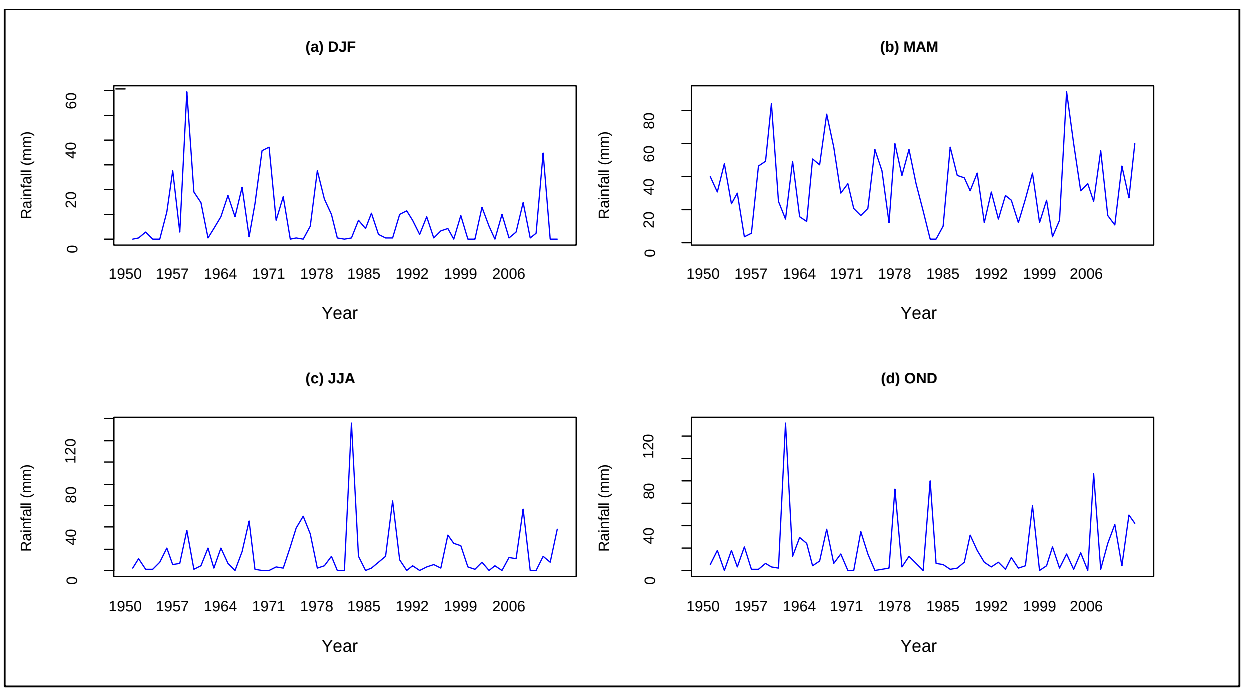


Figure 4.2 Seasonal rainfall trends for Lodwar between 1950 and 2012

The results revealed high inter-annual rainfall variability (CV >90.0%), with non-significant ($p<0.05$) decrease in March- May (MAM) rainfall, and increase in October - December (OND) rains for the period 1950-2012. Although none of the season's trends observed are statistically significant (at $\alpha = 0.05$). The study results is consistent with other seasonal analysis (Mutai *et al.* 2000; Schreck and Semazzi 2004; Shisanya *et al.* 2011), where MAM season rains showed a downward trend, while the OND season appeared to have a slight upward trend in parts of arid environments of Kenya. Although, these seasonal rainfall time series results did not reveal a statistically significant (at $\alpha = 0.05$) trend. The seasonal rainfall upward and downward trends in the time series were observed in Lodwar. Overall, the observed monthly, seasonal and annual rainfall variability implies that rainfalls are highly unpredictable, and therefore, the region exhibit non-equilibrium dynamics as described by Ellis and Galvin (1994) in similar ecosystems. The unpredictable rainfall trends in temporal domain, provides the incentives for debating on the rainfall variability in the arid environment and by extension on climate change. However, previous studies by Mutai *et al.* (2000) have confirmed that the East African short rains in October–December (OND) have a positive correlation with El Niño–Southern Oscillation (ENSO).

4.3.2 Trends analysis for annual rainfall

The study findings showed that long-term mean annual rainfall estimated during 1950-2012 for Lodwar was 216.77 mm, with the highest and lowest rainfall recorded in 1982 (725.1 mm) and 1984 (54.2 mm) respectively. In Lodwar, the highest and lowest rainfall monthly mean totals were observed in 1982 (60.42 mm) and 1984 (4.51 mm) respectively. Figure 4.3 illustrates annual total rainfall trend pattern for Lodwar for the period between 1950 and 2012.

Mann-Kendall test statistic result for period 1950-2012 showed that there was a positive value for overall annual total rainfall in Lodwar though the trend was not significant at 5%. The same is observed for the two intervals identified. The first climatology (1961-1990) with a mean of 235.7 mm indicates that 1961, 1966, 1967, 1974/5, 1977, 1979, 1982 and 1988/9 had normal mean rainfall precipitation based on the standardized residuals estimation. For the second climatological period 1971-2000, there seemed to be an evidence of a general decrease in rainfall regime though generally not statistically significant at 95% confidence level. The result from the two periods 1961-1990 and 1971-2000 mean statistical test show that there was no evidence of any climatological change. The normal mean rainfall was recorded for 1972/3, 1974/5, 1977, 1979, 1982, 1985, 1988/9 and 1996/7 based on rainfall standardized residual calculation (Figure 4). A closer look at the results further revealed that there was no trend observed for the rainfall received in all the rainfall regimes. However, the first climatology (1961-1990) had more years with below normal rainfall though not as severe as that the subsequent period observed between 1971 and 2000 in Turkana. The amount of annual rainfall and its seasonal distribution are crucial factors for understanding the spatial distribution of different ecological units (Bailey 1998; Herrero *et al.* 2010). Therefore, our study results could be of great importance for detecting climatic impacts on arid and semi-arid ecosystems in the region.

The findings of this study corroborate previous observations by King'uyu *et al.* (2000); Mutai *et al.* (2000); Hastenrath et al. (2011); Omondi *et al.* (2013); Cook and Vizy (2013) conducted in other parts of eastern Africa region. Shisanya *et al.* (2011) on the other hand observed that inter-annual rainfall variability in the arid and semi-arid lands (ASALs) of Kenya was decreasing significantly, in contrast to Lodwar weather station results where seasonal and annual rainfall show a non-statistically significant results (at a = 0.05) with implication that there was no trend observed over the last six decades. It is essential to note that most of the rainfall was received during the long rains growing period in MAM, though April is known to be the peak recorded decreasing trend.

The knowledge of trends and variations of current and historical climate variables is pertinent to future development and sustainable management of arid and semi-arid environments. That notwithstanding, the amount of annual rainfall and its seasonal distribution are crucial factors for understanding the spatial distribution of different ecological units (King'uyu *et al.* 2000). The temporal rainfall variability results suggest significant implication for practical management of the drought prone region of Turkana. However, there was no significant overall annual trend observed over time, even on small scales time frame, hence it is particularly hard to gauge the rainfall changes in Lodwar. There is also limited evidence to suggest that there have been significant rainfall changes in the area to warrant what is commonly referred as climate change over Turkana. The climate data analysed show rainfall variability to be a normal characteristic of the study location over the past 63 years.

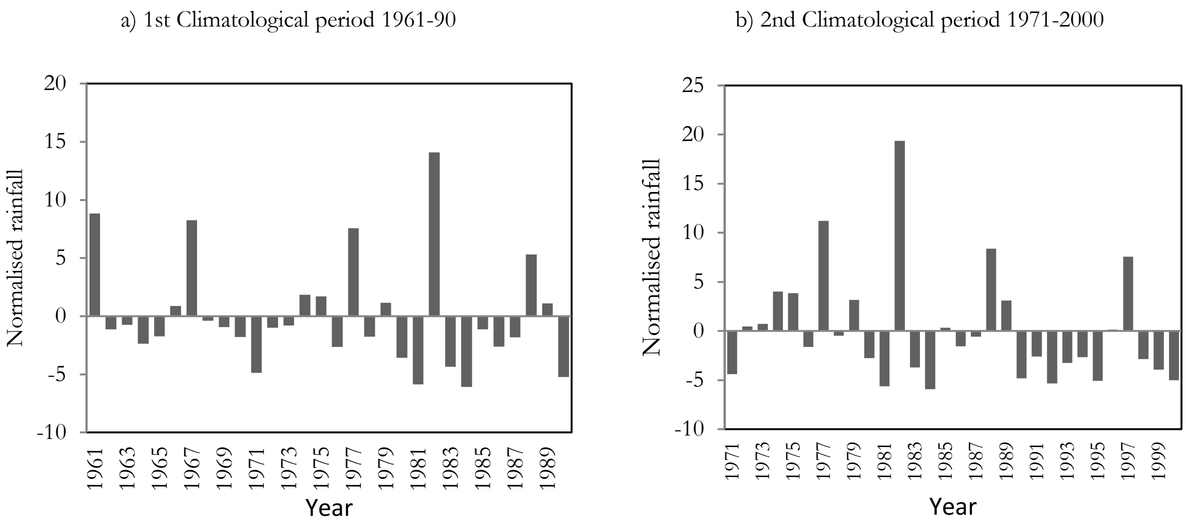


Figure 4.3 Annual rainfall anomalies for the first climatological period 1961-90, and second period 1971-2000 in Lodwar

4.3.3 Monthly and seasonal temperature trend analysis

Temperature series was investigated for monthly, seasonal and annual temporal trends to provide a micro scenario for temperature variability in Lodwar between 1979 and 2012. Results showed that January had the highest mean monthly temperature of 36.97°C and December with the lowest 20.22 °C. Mean monthly annual highest and lowest temperatures were observed in December 1999 (23.7°C) and July 2011 (11.1°C) respectively. However, the lowest of the maximum temperatures and highest of the minimum temperature were recorded in May 2012 (25 °C) and December 2006 (19.1 °C) respectively. The Mann-Kendall test statistics results for both minimum and maximum temperatures are shown in Table 4.2. For the increasing trend, it's only the months of January, August and November for the entire study period had trends with maximum temperature values which were statistically significant. The other months showed slight negative and positive trends both for minimum and maximum temperature data, though the changes were not statistically significant at α = 0.1 or 0.05 (Table 4.2). The monthly temperature data for period 1979-2012 are generally dominated by increasing maximum temperature trend though not statistically significant, expect for the months of January, August, and November. For the minimum temperature, negative Z values were observed for the month of March, May and October which were statistically significant at α = 0.05, which implies a significant decreasing trend of minimum temperatures.

Table 4.2 Mann-Kendal derived trend values for temperature estimates for Lodwar

Variable	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Period
Monthly Min Temp trend (MK Test stat)	0.103	0.096	0.223	0.16	-0.08	-0.14	0.17	-0.02	-0.12	**-0.29***	0.136	-0.08	1979-2012
Monthly Min Temp trend –First climatology (MK Test)	-0.014	-0.014	**-0.414***	0.0214	**-0.268***	-0.223	-0.185	-0.155	-0.197	**-0.259****	0.055	-0.162	1981-2010
Monthly Max Temp (MK Test stat)	**0.13***	-0.23	-0.13	-0.13	-0.04	-0.03	0.15	**0.35***	-0.01	-0.06	**0.39***	0.11	1979-2012
Monthly Max Temp trend (C)-First Normal (MK Test)	**0.055***	**-0.309***	-0.116	-0.194	0.0243	-0.009	0.16	**0.35***	-0.065	-0.137	**0.28***	0.021	1981-2010

* Figures show linear trends that are statistically significant at 5%, Mann-Kendall -MK

Figures 4.4 to 4.7 illustrate the results of seasonal standardized temperature trends between 1979 and 2012 in Lodwar. The findings show that 42% of months had positive trends value for seasonal maximum temperature based on Mann-Kendall test statistics, and the computed probability were all statistically significant at 90% confidence interval. Temperature results suggest an increasing trend for both maximum (Tmax) and minimum (Tmin) temperatures. Overall, a rise in minimum (0.2°C), maximum (0.1°C) and mean (0.13°C) temperature occurred between 1979 and 2012. The DJF season recorded the highest mean temperature (36.27 °C), while OND season had the lowest mean minimum temperature of 20.87°C between 1979 and 2012 in Lodwar (Table 4.3). The effects of warming temperatures are already being felt in the region. The results are consistent with previous studies in the region by King'uyu *et al.* (2000), Anyah and Semazzi (2006) on temperature variability trend anomalies. Studies by Omondi *et al.* (2013) similarly highlighted a general increasing warm temperature, particularly at night, while cold extremes are decreasing in the Horn of Africa region.

Table 4.3 Mean seasonal temperature statistics between 1979 and 2012 in Lodwar

Seasons (°C)	DJF dry-season		MAM long-rains		JJA dry-season		OND short-rains	
	Tmax	Tmin	Tmax	Tmin	Tmax	Tmin	Tmax	Tmin
Mean	36.27	21.12	34.86	22.50	33.54	21.42	35.16	20.87
SD	2.32	1.21	3.04	0.62	2.07	0.50	1.89	0.69
P-value (Zstat.)	**0.061**[a]	**0.053**[a]	**0.091**[a]	**0.062**[a]	**0.088**[a]	**0.056**[a]	**0.059**[a]	**0.1**[a]

[a]Seasonal data shows statistically significant trend (at $\alpha < 0.1$) with an increasing trend.

The results are consistent with Collins (2011) which indicated that rapid warming from 1979 onward was witnessed in Kenya. Overall temperature trend follows the seasonal distributions for the study period and all the seasons show a high variability and anomalies. Previous studies by King'uyu *et al.* (2000) analysed trends of minimum and maximum surface temperatures over eastern Africa, and their results also indicate a reversal of anomalies over the region, with the northern part of eastern Africa generally exhibits night-time warming, whereas the southern region has been experiencing cooling during the more recent period. This result provides a clear understanding of the seasonal changing patterns in temperature at local level, and confirms that global warming can be revealed even at local scales.

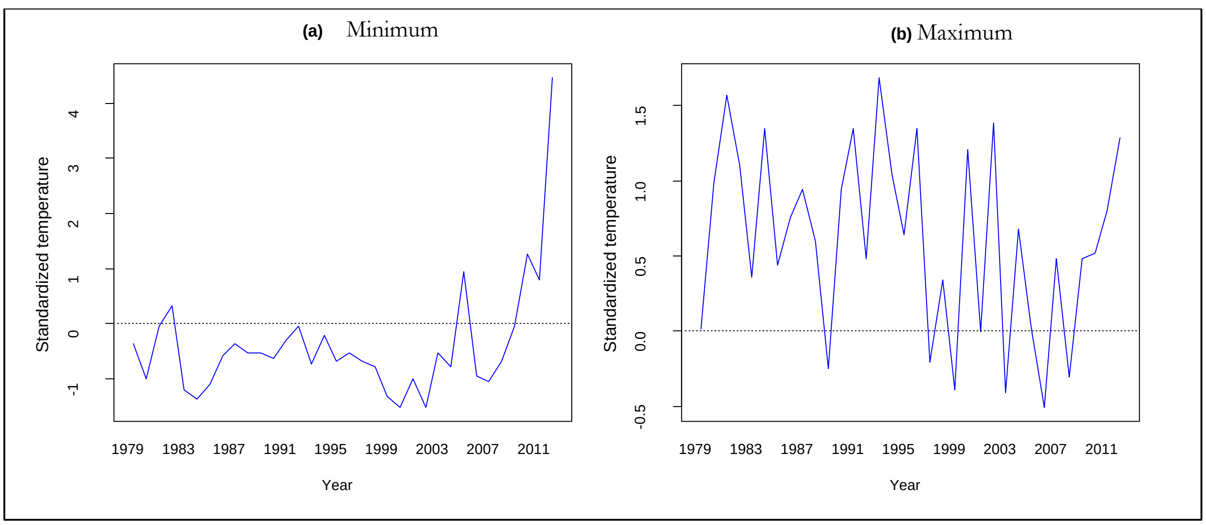


Figure 4.4 DJF standardized minimum and maximum temperature trend from 1979-2012 in Lodwar

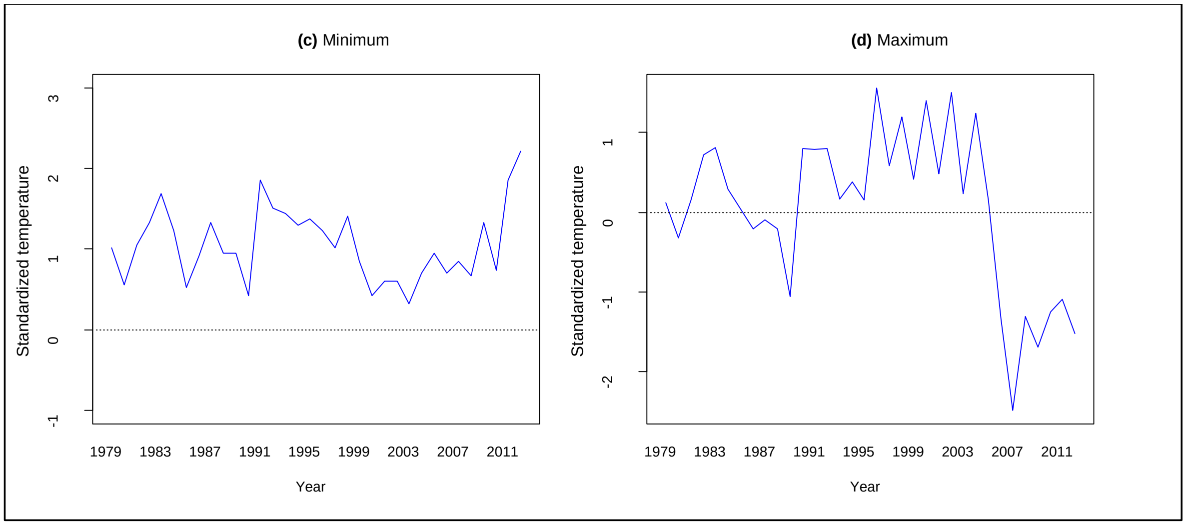


Figure 4.5 MAM standardized minimum and maximum temperature trend from 1979-2012 in Lodwar

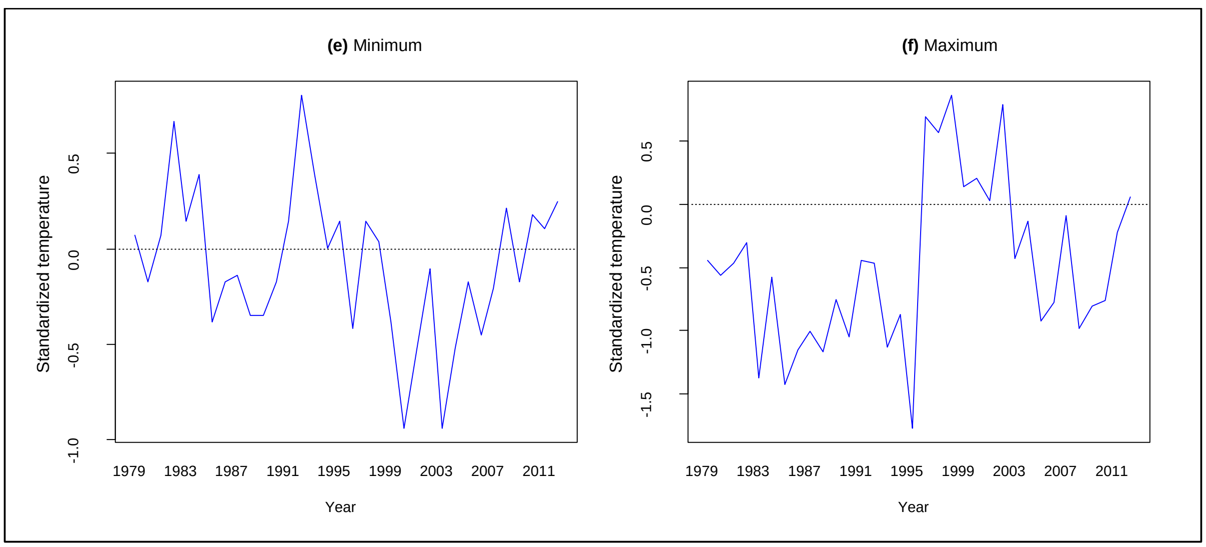


Figure 4.6 JJA standardized minimum and maximum temperature trend from 1979-2012 in Lodwar

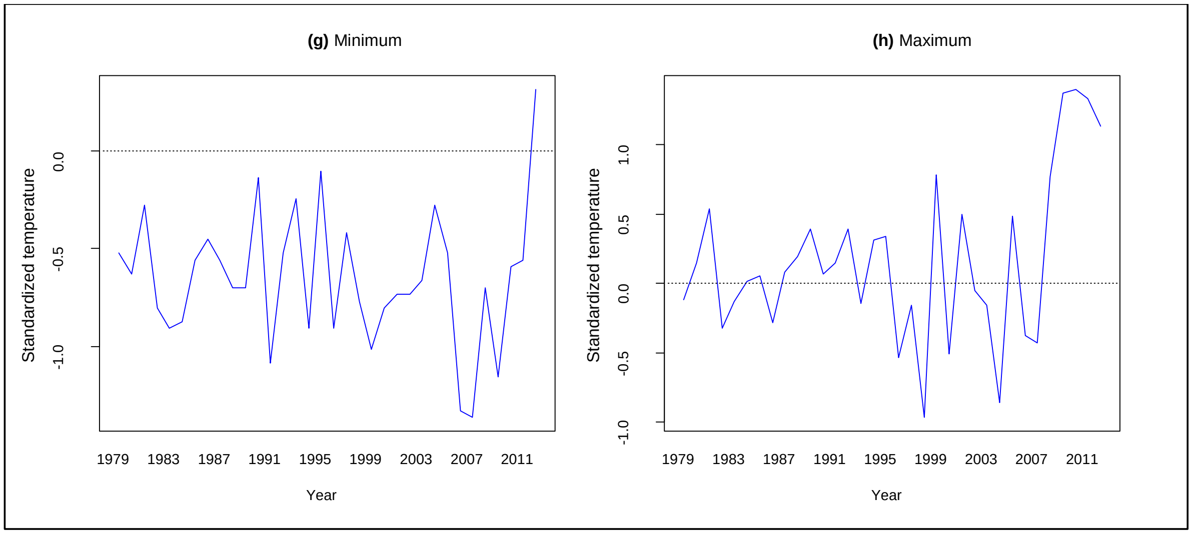


Figure 4.7 OND standardized minimum and maximum temperature trend from 1979-2012 in Lodwar

4.3.4 Correlation between rainfall and temperature

The Pearson correlation results on seasonal mean rainfall and temperature for the period 1979-2012 are listed in Table 4.4. The number reflects the correlation between these two sets of climate variables and it's within the range of -1 to +1. The number -1 means the variables are inversely correlated, meaning that they change over time in the opposite direction as each other. In this study, results showed that MAM seasonal rainfall had a negative correlation that was not statistically significant (at p< 0.01) with the maximum temperature (Tmax), i.e. the higher the maximum temperature during MAM the lower the rainfall. Surprisingly, the OND seasonal rainfall in Lodwar had a positive correlation with the maximum temperature (Tmax), which implies that the two climate variables move exactly in the same direction in the same season with each other. The positive association was statistically significant at both 1 and 5%. However, another interesting pattern in the correlation was observed between MAM seasonal rainfall and minimum temperature (Tmin), which was negative and statistically significant at 5%.

Table 4.4 Pearson coefficient between seasonal mean rainfall and temperature and their associated significance levels (*p* values)

Seasons	Temperature				Rainfall	
	Tmax	*P* value	Tmin	*P* value	Mean (mm)	Std. dev
Mean rainfall MAM	-0.197	0.2546	-0.202*	0.0247	30.71	25.38
Mean rainfall OND	0.076**	<0.0001	-0.139	0.3356	17.08	18.24

*significant at $P<0.05$, **significant at $P<0.01$; Maximum temperature – Tmax, Minimum temperature-Tmin

The finding adds to other previous studies in the region (Camberlin *et al.* 2001) that revealed a significant correlation between the 'short rainy' season in OND and corresponding maximum temperature. On the other hand, it was observed that the minimum temperature (Tmin) is not significantly correlated with OND seasonal rainfall in the area; this may be attributed to other factors that contribute to temperature variation other than precipitation. Overall, previous studies by Collins (2011) revealed that the climate change over eastern Africa is predominantly not a result of variations in the El Niño–Southern Oscillation. Instead the climate changes occur owing to other natural variability of the climate and or may be a result of human activity.

4.4 Conclusion and Recommendations

Given the need to devise a robust meaningful method that will enable government and development agencies to discern the temporal dynamics of rainfall and temperature at a given scale, this study has demonstrated how statistical analyses and historical data records could be used to characterize trends at a local scale. Studies of climate variability at local level are important for climate change impact studies: which are crucial in planning adaptation and management of natural resources among others. At the same time, potential impacts that any changes in climate could have on the ecologically sensitive ecosystems can be determined. As observed elsewhere, warming temperatures in the arid ecosystems could affect key sectors, especially pastoral production system which is the predominant land use activity in the arid and semi-arid lands of Kenya. This study finding has implication for decision making in the management of arid environments in the region.

Overall, the findings of this study revealed the following key conclusions;

i) The study revealed large variability and unpredictability of monthly and annual rainfall (coefficient of variation-CV >90.0%), with no significant trend patterns for period 1950-2012 in Lodwar, Turkana. However, the result reinforces earlier observations that year to year, season to season variability is persistent in arid environment of Kenya.

ii) In spite of the absence of definite trend patterns for the overall annual rainfall in Lodwar, the Mann-Kendall statistical test revealed positive and negative trends for the individual monthly rainfall observed. For example, the month of December showed positive trends; while the rest of the months had no trend for the discrete periods observed except for January, February, April and July which showed decreasing rainfall pattern. However, there was no significant decreasing rainfall trend observed.

iii) Rainfall seasonality results, revealed decreasing rainfall trend for March – May (MAM) season, while the Oct- Dec (OND) rains had a slight decrease for the period 1950-2012. But none of the seasonal trends were statistically significant. The study area recorded relatively low mean annual rainfall for the ‘long rains’ (30.7mm) and ‘short rains’ (17.2mm) over the same period. However, it was concluded that the Oct - Dec (OND) rains are becoming more reliable compared to the March – May (MAM) rainfall season in the arid and semi-arid lands of Kenya.

iv) Slight warming is observed across the study area during the period 1979-2012, the warming received in Oct-Dec (OND) had a significant increase in temperature. This result is also consistent with Hulme *et al.* (2001) who examined the period 1901–95 and notes that a slightly larger warming in Africa occurs in the months of Oct – Dec (OND) than in the months of March – May (MAM).

v) The findings demonstrated that a significant rise in both minimum (0.2°C) and (0.1°C) maximum temperatures occurred between 1979 and 2012, and this corroborate the recent trends of global warming as reported by the latest Intergovernmental Panel on Climate Change (IPCC 2012) report.

The findings observed could guide various decision makers in Turkana to see, on a local scale, what temperature changes are being observed and to help them better plan for a changing climate. This study did not establish the causes of differences in trend and means for seasonal temperature trends; this could probably be investigated further with the aid of a general circulation models. However, it suggests further research into the underlying local factors influencing the climate of the area, causes for the differences in monthly mean temperature, actual effects of ENSO on rainfall totals and the influence of Indian Ocean over northern Kenya. At the same time aspects of the impacts of changing land use patterns, degradation and global warming on the micro-temperature also require more consideration in future research. The study recommends that future studies should build on this finding to document spatial-temporal rainfall and temperature trends using datasets from more than one meteorological station.

CHAPTER FIVE

ADAPTATION AND COPING STRATEGIES TO DROUGHT STRESSES BY TURKANA PASTORALISTS OF NORTHERN KENYA

Abstract

This study unearths drought characteristics, and highlights myriad responses to drought stresses by Turkana pastoralist of North-western Kenya. Multiple data collection techniques including socio-economic interviews with 302 households, focus group discussions, informal interviews with pastoralists and *in-situ* rainfall data from a meteorological station were used to capture various aspects of the study. Standardised precipitation index (SPI) was used to quantify different drought categories between 1950 and 2012. Results established that extreme prolonged drought events were the most frequent, and have impacted negatively on lives and livelihoods. However, this study reveals a myriad of strategies households are using to adapt to or cope with the vagaries of drought. The long-term adaptation strategies used include diversification of livelihood sources, livestock mobility, diversification of herd composition and species, and sending children to school. The findings indicate that pastoralists also use considerable short-term adjustments in coping with impacts of droughts. The conclusion is reached that reducing risks, constraints to, and expansion of opportunities for households' resilience to drought are desirable policy objectives.

Keywords: Drought, adaptation, coping, climate change, pastoralism, Turkana

5.1 Introduction

Drought is often one of the most devastating but least understood weather phenomenon in the tropics, largely because of its slow onset and its accumulating impacts over time. Although definitions of drought may vary depending on context, it is generally an extended period of months or years, in which precipitation is less than the annual average, resulting in sever water scarcity (Wilhite 2000; Downing and Bakker 2000; Whetherald and Manabe 2002). According to The World Meteorological Organization (WMO), droughts are classified as either a meteorological (lack of precipitation over a region for a period of time), hydrological (a period with inadequate surface and sub-surface water resources), agricultural (a period with declining soil moisture and con sequent crop failure due to lack of surface water resources) or socio-economic drought (failure of water resources systems to meet demands, which impacts human activities both directly and indirectly). The Kenya Meteorological Services (KMS) defines normal meteorological drought as a situation when rainfall over an area is less than 75 percent of the climatological normal (i.e., a rainfall deficiency of 25%). This definition is extremely crude as it gives little information about the temporal distribution of rainfall (Wilhite and Glantz 1985). On the other hand, one could define optimal rainfall as sufficient rainfall in amount and distribution over time and space to meet the needs of specific livelihoods. For the Horn of Africa region, drought situation has become increasingly severe during the last decade, with rainfall being at least 50%-75% below normal in most areas and not enable to satisfactory support crop and pasture growth for livelihood security (Nicholson 2014). Studies by Huho and Mugalavai (2010), and Nkedianye *et al*. (2011) indicates that Kenya have experienced increase in drought frequency from once in every 10 years in 1960/70's to once in every 5 years in 1980's; and once in every 2-3 years in 1990's to now increasingly unpredictable since the year 2000. According to Intergovernmental Panel on Climate Change (IPCC 2012) report, there is likely to be a marketed increase in drought severity over much of Eastern Africa by 2050s, which ultimately will threaten climate sensitive economic sectors.

Studies show that drought poses serious challenges for populations whose livelihoods depend principally on natural resources (Below et al. 2010). The arid and semi-arid lands (ASALs), which faced increasing and decreasing drought frequency and intensity since 1960s, is one of the most vulnerable and drought prone regions in Kenya (Nkedianye *et al.* 2011). Despite the vulnerability, pastoral economy in ASALs of Kenya accounts for 90 percent of employment opportunities and 95 percent of family incomes and livelihood security (ASAL Policy 2012). Given the changing global climate, coupled with expected increase in evapotranspiration due to increase in temperatures, the ASALs are expected to experience frequent climatic extremes, increased aridity, increased water stress, decreased yields from rain-fed agriculture, and increased food insecurity and malnutrition (Thornton and Lipper 2014). Adaptation and coping are therefore necessary in reducing vulnerability to drought stresses as well as to prepare for any possible future extreme climate event. The Intergovernmental Panel on Climate Change reports (IPCC 2001, 2007, and 2012) defines adaptation as adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects which moderates harms or exploit beneficial opportunities. Adaptation therefore involves adjustments in reducing vulnerability of households to climatic variability and change (Adger *et al.* 2007). On the other hand, Blaikie *et al.* (1994) define coping as the manner in which people act within existing resources and range of expectations in a given context to achieve various ends. Therefore, adaptation involves longer-term shifts in livelihood strategies, while coping involves temporary adjustment to respond to change or mitigate shocks and stresses on livelihoods (Eriksen *et al.* 2005; Mogotsi *et al.* 2011). However, adaptation or coping of people to different hazards vary from household to households and region to region based on existing support system to increase the resilience of affected individuals (Brooks *et al.* 2005).

Various pastoral communities have been studied for decades on their adaptation strategies to changing environmental conditions (Saitoti 1986; Ellis 1998; Campbell 1999; McCabe 2004; Davies and Bennet 2007; Neely *et al.* 2009; Oba 2014). Literatures show that livelihood of most pastoralists have evolved to some extent under variable climatic conditions in the arid and semi-arid environments (Blench 2000; Little 2003; Notenbaert *et al.* 2007; Thornton and Gerber 2010; Notenbaert *et al.* 2012). The African Union (African Union 2010, p. 21) reports that pastoralism have "evolved over generations as a response to marked rainfall and temperature variability", with immense potential for reducing poverty, generating economic growth, managing the environment and promoting sustainable development. Other research has shown that pastoralists have an intimate relationship with their environment and a rich knowledge that enables them to both protect and exploit changing rangelands' conditions on which they depend (McGahey *et al.* 2007; Notenbaert *et al.* 2012). In fact, understanding how pastoral communities adapt to and cope with extreme climatic changes and particularly drought becomes even more important as pastoralism in north-western Kenya already faces environmental, political and socio-economic marginalization, violent conflicts over natural resources, and new challenges such as the discovery of oil which is likely to threat pastoralist resilience to drought (Schilling *et al.* 2012). Few studies (Speranza 2010; Silvestri *et al.* 2012; Osano *et al.* 2013) have endeavoured to comprehensively document pastoralists' adaptation and coping strategies to the complexity of drought at a micro-scale. Given the projections for increasing drought impacts in the pastoral areas, it is important to inform policy makers on various adaptation and coping responses at local levels in order to reduce risks associated with drought.

This study therefore set out to examine drought characteristics, identify adaptation processes more broadly as long-term measurers, and analyse temporary coping responses to drought in North-western Kenya. Knowledge about pastoralists' adaptation and or coping responses to drought stresses will guide possible intervention measures, as well as better inform policy designed to reverse the decline in pastoral production systems and hence ensure continued sustainability of rural livelihoods in arid and semi-arid environments.

5.2 Material and Methods

5.2.1 Study area

The study was conducted in Turkana County, located in North-western Kenya. The detailed description of the study area and research design is found in Chapter Three of the Thesis.

Turkana region like any other counties of Northern Kenya have experience major incidences of droughts events. The occurrences of drought and the number of people affected in Kenya between 1978 and to 2011 are shown in Table 5.1.

Table 5.1 The occurrence of drought events and people affected from mid 1980s to 2012 in Kenya

Year	*Local name of the drought*	Local perception on extent of spread	Number of people affected
2010-2011		Widespread	3,750,000
2008-2009	*Lomoo*	Widespread with deaths of shoats	3,500 000
2005-2006	*Kumando*	Drought and bad hunger, and drought which terminated everything	3,400,000
1999-2000		Widespread	2,400,000
1997	*Etop*	Widespread serious but short drought	1,500,000
1995-1996		Widespread	1,400,000
1993		Widespread	1,200,000
1991-1992	*Lopiar*	Skins everywhere, many livestock Deaths.	1,500,000
1983-1984	*Kilejok, Kidirik*	Widespread with minimal rain, and livestock raiding	200,000
1978-1981	*Loukoi , Lopiar, Atanayanaye*	Animal disease (CCPP, anthrax), security problems, famine	40,000

Source: Adapted from: Swift (1985); Turkana Drought Contingency Unit (1992); and Field data (2013).

5.2.2 Turkana pastoralist

The Turkana, a Nilotic ethnic group, is the dominant community in the study area. Pastoralism is their principle livelihood and it is believed to have evolved under variable climatic conditions, marked by multiple livelihood strategies deployed to changing environmental conditions (Blench 2000; Notenbaert *et al.* 2007). The Turkana people traditionally had 19 territories and 28 small clans, each occupying a defined territory. For centuries, no individual rights to forage exist but crossing to other grazing territories requires permission from the elders and the "*emuron*" or seer of that territory. However, as recently observed rights of access to pasture and water do not translate into utilization as some of the areas are not accessed due to threats of livestock raiding from neighbouring communities. For example, the area around the village Loya is a conflict hot spot between the Turkana and the Pokot as both groups claim communal rights (Schilling *et al.* 2012). Based on an analysis of a local conflict database Schilling *et al.* (2014) report an average raiding frequency of six raids per month in Turkana between 2006 and 2009. The raids do not only cause human suffering directly but also impacts negatively on other households adaptation and coping strategies in the area (Bett and Jost 2009).

Turkana pastoralist like other nomadic communities have traditionally used risk spreading strategies over the years that include moving livestock to access the best quality of pasture and water available, keeping species-specific herds to take advantage of the heterogeneous nature of the disequilibrium environment, and diversifying economic strategies to include agriculture and wage labour, beekeeping among others (Swift *et al.* 2001; Watson and van Binsbergen 2006). Other strategies employed include keeping a mixed stock of herds as insurance against total loss of livestock in case of drought. The livestock species kept include camels, cattle, sheep, goats and donkey with different forage and water requirements and variable levels of resilience during drought periods.

5.2.3 Rainfall data

The data used in this study includes precipitation records from Lodwar station obtained from the Kenya Meteorological Services (KMS) in Nairobi, Kenya. The precipitation datasets include observations spanning from 1950 to 2012 and cover a period over 30 years which is considered to be long enough for a valid climate statistical analysis. The Standardized precipitation index (SPI) was used to analyse drought severity. The SPI was calculated for 12 months for the period between Jan 1950 and Dec 2012. In the analysis, the negative values of SPI are considered as dry and positive values for wet periods. The SPI has been used previously in Australia (Abawi *et al*. 2003), in Mexico (Giddings *et al.* 2005) and in parts of Kenya ASALs by Huho *et al*. (2010) to examine drought severity. The SPI is computed by dividing the difference between normalized seasonal precipitation and its long-term seasonal mean by standard deviation as follows:

$$\text{SPI} = \frac{Xij - Xim}{\sigma}$$

Where:

σ = Standard deviation

Xij = seasonal precipitation at the ith synoptic station

$X\imath m$ = Long term seasonal mean precipitation

The Meteorological drought was considered to have occurred when the SPI value was negative and ended when the value became positive. The droughts were categorized as mild when the SPI value ranged from 0 to -0.99; moderate with the value from -1.0 to -1.49; severe when the value ranged from -1.5 to -1.99 and extreme when the value ranged from - 2.00 and below. The normal mean precipitation is when SPI was zero (0.00).

5.3 Results and Discussion

5.3.1 Drought characteristics

The result shows that severe and extreme droughts were experienced between 1950 and 2012 in the study area. The severe droughts year were observed in 1955, 1957, and 1964, while extreme droughts in 1950, 1960, 1980, 1990, 1995, 2000, 2008 and 2009 (Table 5.2). However, the finding revealed that 2010/2011 was a normal to moderate rainfall years in Turkana (Figure 5.1), despite the hype that it was the worst drought over the last 60 years in the region. However, the finding confirms that Meteorological drought year matches well with the historical records of actual droughts observed by the respondents. Thus, statistical counts of drought spell from SPI values could to be used to obtain the overall drought characteristics in the study area. From the findings, the extreme drought events have increased over the last 63 years, with 28.5% occurrences between 1950 and 1970, to 47.9% over the last two decades between 1990 and 2012 in the study area.

Summation of severity index indicates that approximately 80% of prolonged droughts experienced between 1950 and 2012 were extreme (Table 5.3), with a likely negative effects on livelihoods security of the pastoralists in Turkana. The concurrence of such droughts has been associated with the El Niño Southern Oscillation (ENSO) phenomenon which cause below normal rainfall in Kenya (Anyamba, *et al.* 2001). The climate of the study area is also thought to be influenced by anthropogenic impacts from land use changes, which affect vegetation cover, surface albedo and soil moisture (Douville 2002). The increasing severity and frequency of drought occurrence is an indication that the region is getting drier reflecting the observed changes in the arid north-western Kenya. This observation concurs with Howden (2009) who notes that the climatic conditions of northern Kenya is getting drier.

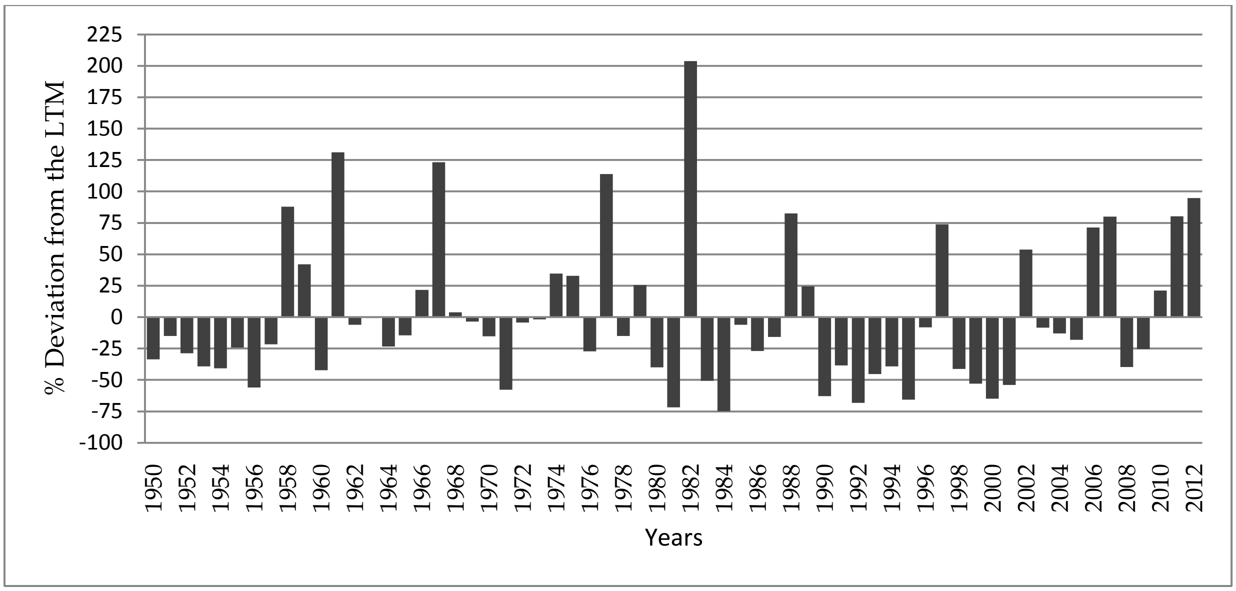


Figure 5.1 Percent mean annual rainfall deviation based on 1950 – 2012 long-term mean (215.7mm) in Turkana.

Table 5.2 Drought Severity in Turkana between 1950 and 2012

Year	**Annual rainfall total (mm)**	**Standard Deviation (σ)**	**Drought severity index (SPI-** Standardized Precipitation Index**)**	**Drought Category**
1950	143.1	24.7	- 2.68	Extreme
1955	163.3	20.2	- 1.94	Severe
1960	124.7	15.4	- 3.37	Extreme
1965	184.2	31.0	- 1.16	Moderate
1970	182.7	26.2	- 1.22	Moderate
1975	286.6	35.7	(2.62	Normal
1980	129.3	22.5	- 3.19	Extreme
1985	202.5	26.2	- 0.49	Mild
1990	80.2	8.1	- 5.01	Extreme
1995	74.1	8.6	- 5.24	Extreme
2000	75.9	12.7	-5.27	Extreme
2005	176.6	24.3	- 0.18	Moderate
2006	369.8	44.0	5.70	Normal
2007	388.0	31.1	6.37	Normal
2008	130.2	16.7	- 3.16	Extreme
2009	160.8	30.5	- 2.03	Extreme
2010	261.2	29.0	1.68	Normal
2011	77.3	8.8	- 1.00	Moderate
2012	420.0	38.2	7.16	Normal

Source: Author compilation

Table 5.3 Prolonged drought periods

Drought Period	**Maximum Severity Index (SPI- Standardized Precipitation Index)**	**Drought Category**
1952 - 1956	- 4.47	Extreme
1962 - 1965	-1.87	Severe
1980 - 1984	- 5.97	Extreme
1990 - 1995	- 5.24	Extreme
1999 - 2001	- 5.17	Extreme
2008 - 2009	- 3.16	Extreme

Source: Author compilation

5.3.2 Impacts of drought on pastoral livelihoods

Figure 5.2 gives a summary of the drought impacts on pastoralists' livelihoods. Majority of the respondent reported livestock mortality (22%) as caused by recurrent droughts in the study area. Other impact observed by the respondents are drying up of water sources (18%), declining pasture availability and access (14%), food shortage (15%), increasing food prices (12%) and loss of income (10%). Further discussions with the key informants revealed that previous drought also resulted in livestock diseases outbreaks such as *peste des petit ruminants* (PPR), and violent inter-community conflicts that result in livestock losses to raiders. Studies (Huho *et al.* 2010; Nkedianye *et al.* 2011) reported a positive correlation between drought severity and number of livestock losses in northern Kenya. However, it is worth reiterating that livestock deaths in the study area could be a result of other factors such as livestock diseases and raiding all exacerbated by drought.

The drying up of water sources and reduction in water availability are indicators of hydrological drought. Turkana is known to be permanently under water stress with seasonal rivers traversing through the county. Results show that majority of households at the time of interview were trekking for more than 15 km in search of water. However, recent discovery of underground water source is widely viewed by respondents as the panacea to ending chronic water shortage in the area. Studies (Opiyo *et al.* 2011) have also shown that water is a critical determinant of pastoral production systems in the ASALs. Drought was reported to have had other far reaching consequences which include decline in crop yield, increase in food prices, loss of income and decline in pasture availability and access as observed by the respondents. In general, recurrent drought impacts exacerbate the many existing challenges in pastoral areas (Kates 2000), and, as mentioned earlier, it can often be very complex to identify drought *per se* as the only direct driver of the reported changes.

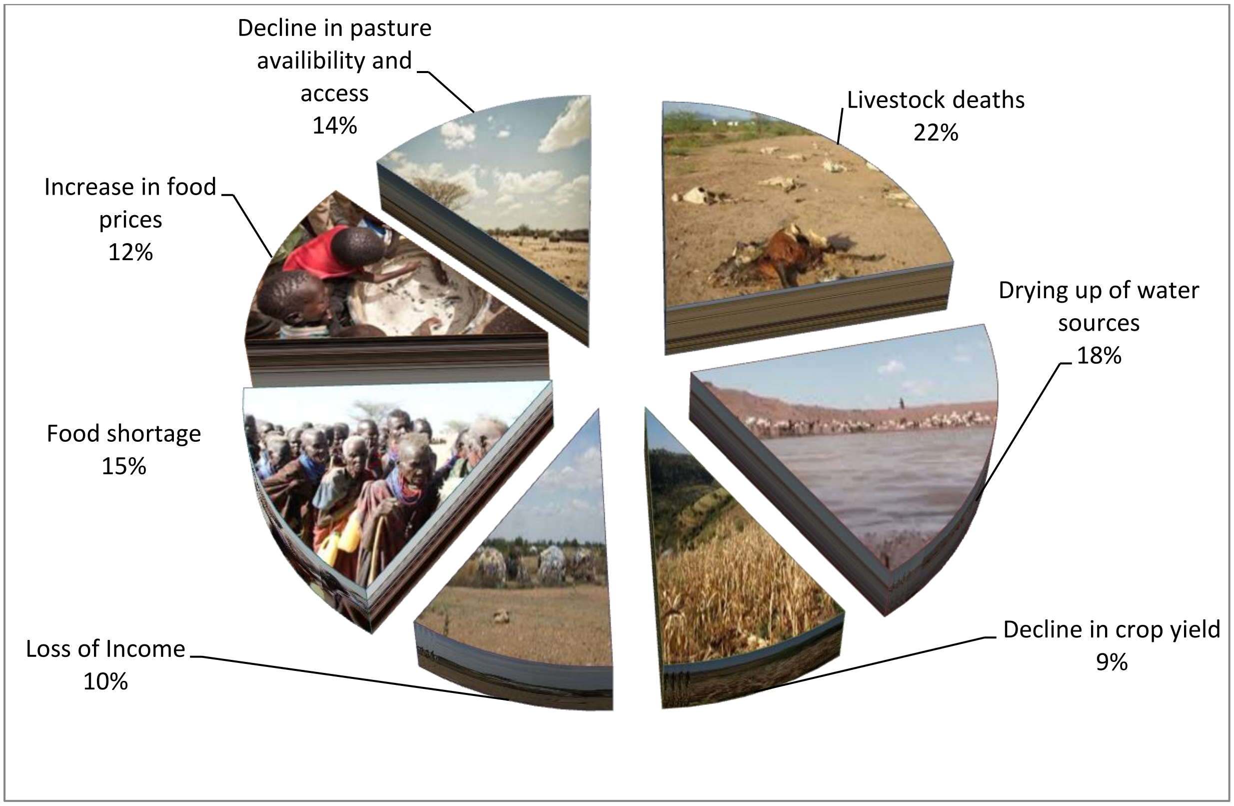


Figure 5.2 Impacts of drought on Turkana livelihoods

5.3.3 Turkana's adaptation and coping strategies to drought

The Turkana community has a long history of proving its capability of responding to extreme environmental conditions (McCabe and Ellis 1987; Handley 2012), despite the perceived belief on their inability to withstand shocks and stresses. This study revealed a myriad of actions and strategies households are using to adapt to or cope with the vagaries of drought. The discussion that follows highlights some of the multiple strategies deployed in response to changing conditions by the respondents.

5.3.3.1 Adaptation strategies

In the study area, majority of households are pursuing a number of adaptation strategies to mitigate adverse impacts of drought. Figure 5.3a summaries a number of adaptation techniques and the percent of respondent using the strategies. Diversification of livelihood (58.8%), mobility (59.2%), training on animal production (58.8%), change of livestock herd composition

(52.9%), sending children to school (55.9%), increase the sale of livestock and livestock products (51.5%) were identified as some of the most commonly used adaptation strategies in the study area. Other adaptation strategies used include increase in sale of livestock, preserving livestock feed reserves, development of new water sources, cash transfers from relatives, livestock insurance and use of early warning information. The details of these adaptations measures are explained below.

Diversification of livelihood is a major adaptation strategy in the study area practiced by more than 58% of the respondents. The study revealed that because of frequent drought events in the region, majority of the households undertake a myriad of activities to argument resources from livestock production. In this study, livelihood diversification refer to processes by which households construct a diverse portfolio of activities and social support capabilities in their struggle for survival and in order to improve their standards of living (Ellis 1995). This implies that livelihood diversification is not synonymous with income diversification. According to Reardon and Vosti (1995), the rationale for diversification is to create a portfolio of livelihoods with different risk attributes so that drought risk can be managed *ex ante* and that recovery is easier *ex post*. The livelihoods diversification reported by respondents were both on-farm (35.1%, n=106) and off-farm (81.46%, n=246) activities. The on-farm activities include mainly crop farming (sorghum, maize, green grams, cowpeas and vegetables), poultry and eggs production and aloe production. Majority of respondents prefer to engage in non-climate sensitive off-farm activities such as micro-business/small-scale, casual labour, artisan, salaried/fixed employment, charcoal burning. Other off-farm activities include harvesting of wild fruits for food, honey production, basket making and handicraft from palm tree. According to key informants, most of the livelihoods diversification activities have been adapted to complement pastoralism, rather to substitute livestock production in the area. Interestingly, Schilling *et al.* (2010) reported that most of these activities are practiced by women. While no gender aggregation was conducted in this study, other research studies (Njiru 2012; Fernando 2002) have revealed increasing involvement of women in livelihoods diversification in the area.

Mobility is a well-known primary risk reduction strategy, particularly in times of drought and other processes that encroach slowly on pastoralists' rangelands. Results show that majority of the respondents (59.2%) view mobility as an adaptation strategy to reduce risk, and also for other economic purposes, to access livestock, markets or urban centres. However, it was observed that the level of mobility differs across the surveyed locations depending on access to grazing land and water resources. Discussion with key informants revealed that herd mobility enables opportunistic use of resources and helps minimize the effects of droughts and other associated hazards. The Turkana's herders were found to migrate across borders, especially to Uganda, South Sudan and Ethiopia to access resources and markets, and are often affected by impacts such as conflicts, diseases outbreaks and recurrent drought. Studies (Ellis and Swift 1988; Little and Leslie 1999) show that seasonal decisions to migrate ensure that households maintain the productivity of their herds and security of their families. This form of mobility is pursued primarily for livelihood purposes and is very strategic (McCabe 2006). Nonetheless, movement of livestock to areas with secure water and pasture resources is an effective strategy against droughts (Niamir-Fuller 1999) and remained important for herders in north-western Turkana County of Kenya.

With the recent discovery of oil in Turkana and changing land tenure systems in the rangelands, mobile pastoralism are becoming increasingly constrained (Kameri-Mbote 2013). Further results show that high rates of declining mobility have been driven by a combination of factors, including major droughts, increased individualization and disruption of social structures, increased competition and violent conflicts over grazing land, and increased land ownership by investors. Even though most pastoralists have become increasingly semi-sedentary, their herds are still quite mobile. A key issue for future of mobility as an adaptation strategy will be the ability of pastoralist to continue managing the rangelands at communal scale, rather than fragmenting rangelands into private and individual tenure systems.

Training on livestock health was reported by respondents (58.8%) as a strategy for income diversification to reduce risks associated with recurrent drought. This is partly due to increased number of community-based animal health workers as an important animal health delivery channel in this marginal area. Of the livestock keepers who had treated their animals, 85% revealed to have gained skills, training and knowledge from the community-based animal health workers. Traditionally the control of livestock diseases was through the use of local herbs and local techniques which seem to have changed with the emergence of trained community based animal health workers. Key informants revealed that many youths with the animal health trainings and skills support their families with income earned from the sale of veterinary drugs and for attending to sick animals. According to the livestock incidence reports in the study area, the most common diseases are *Peste des Petits Ruminants* (PPR), *Contagious Bovine Pleuropneumonia* (CCBP) and *Contagious Caprine Pleuropneumonia* (CBPP) being endemic in Turkana, Minge, Trypanosomiasis, and Lump skin diseases.

Diversification of herd composition and species are key strategies that have enable pastoralism to thrive in the harsh environmental conditions for centuries (Speranza 2010). Result shows that 52.9% of the households diversify herd composition and keep a mixed of livestock species that include cattle (51.2%) shoats (88.2%), camel (22.9%) and donkeys (12.6%). Livestock type kept consists of mostly local breeds, mainly Small East African Zebu cattle, Red Maasai sheep and small East African goats. Key informant discussions revealed that the locals presently prefer shoat and camels since they are more resistant to drought than cattle. Another possible explanation for increase in shoats is their higher energy and protein content per unit of meat, compared to cattle meat (Devendra 1999). However, the increasingly short timeframes between droughts are likely to be insufficient to allow for adequate accumulation of sustainable herd sizes. Studies by Ali and Hobson (2009), show that increased drought frequency hastens herd depletion, narrows the window for livelihood recovery, and intensifies pressure on depleted water and pasture resources.

Sending children to school to acquire education and trainings is partly seen as an essential strategy to facilitate income diversification for pastoral households in the study area. Results show that 55.9% of the respondent view education as long-term adaptation strategy against drought events. However, for a long time, education for pastoralists' was considered as an exit strategy, and not an end or adaptation in itself. This probably explains why pastoralist areas have had lower enrolment, retention, completion and achievement rates than the rest of the country. For the Turkana's, only 32.3% of the population are enrolled in schools (Migosi *et al.* 2012). This situation is worse when it is viewed in light of enrolment in post primary education. Results revealed that with young boys and girls going to school, there is a likely of redistribution of household tasks including livestock herding to parents and part of children who are not able to access school. In contrast, Fratkin (1986) previously reported that increase in the number of children going to school will result in limited source of labour, whereas labour force is central to other adaptation and risk management strategies in pastoral areas. Arising from this study, there is a probability that education system as currently modelled undermines pastoral livelihood much as it is seen as an adaptation to drought.

Livestock off-take at different stages of a drought is an important adaptation strategy used by the pastoralists. However, Turkana's livestock owners are generally reluctant to sell their livestock because of its high value for subsistence and other social cultural reasons (Schilling *et al.* 2012). However, 32% of the respondents reported that they sell livestock on a regular basis to have a source of cash income. The results also indicate that most respondents sold goats much often than any other livestock type. The motivation regarding the sale of goats was to buy food, medical care, school fees and to obtain cash income for other household needs. The increasing demand and price for livestock products from urban areas also provides another incentive for this adaptation measure.

5.3.3.2 Coping strategies

Turkana pastoralists employ various coping responses against extreme drought events. Unlike adaptations which involve long-term shifts, coping responses were more reactive and mainly involve temporary adjustment of livelihood activities in response to drought. However, selling of livestock and livestock products fall in both categories as pastoralists use this option to cover regular adaptation costs but also to cope with short-term shocks as 70.6% of the respondents stated. Other coping strategies to mitigate drought related risk include: slaughter of old and weak livestock (67.6%), household splitting (64.7%), selling bush products such as *Aloe vera*, charcoal, firewood (61.8%), search for wage labour in towns (61.8%), and minimization of food for consumption (61.8%) (Figure 5.3b). The drought coping strategies reported by respondents varied from household to households based on existing support systems and local knowledge.

The results revealed that some of the Pastoralists coping responses to drought are reactive and mainly involve intensive exploitation of scare resources. However, proactive responses such as selling of livestock at the beginning of drought are few. Further analysis shows that of the 16 coping strategies practiced by respondents, 11 strategies are practiced during drought periods and for more than a month (> 1 month) as shown in Table 5.4. Despite the challenges faced by the coping measures used in the study area, they help households to buffer the adverse effects of droughts.

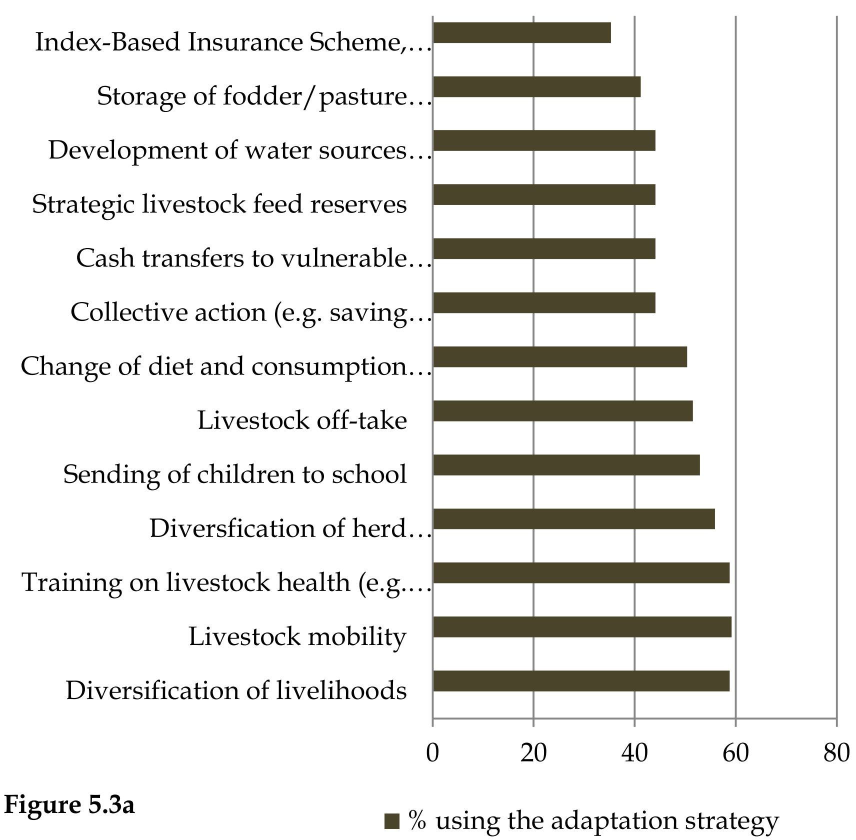


Figure 5.3a

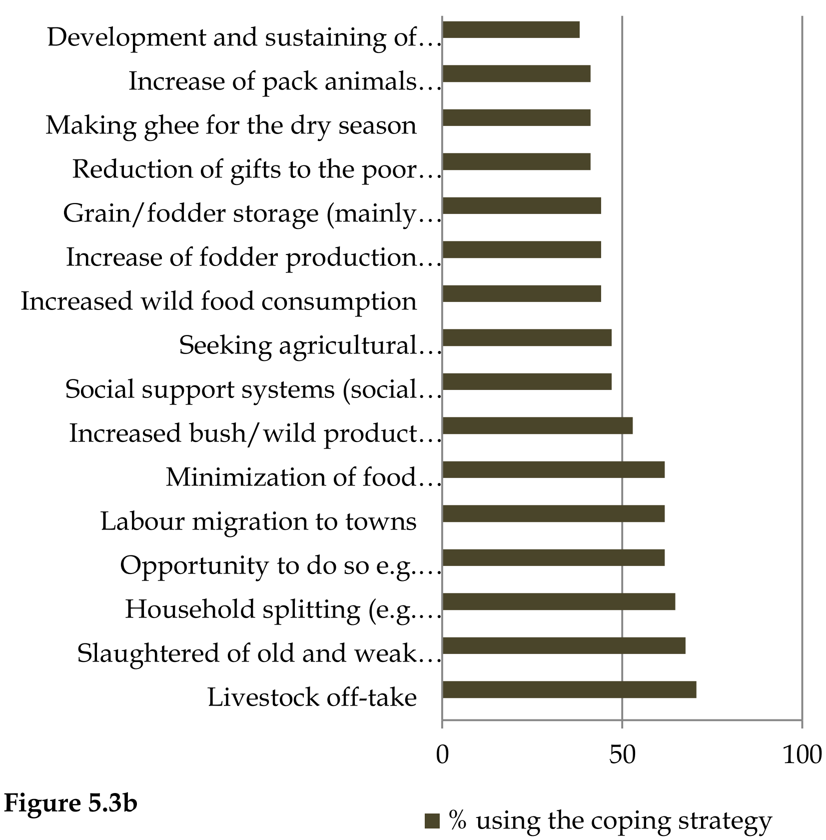


Figure 5.3b

Figure 5.3 Adaptation strategies (a) and coping strategies (b)

Table 5.4 Coping strategies differentiated by observed periods when used and how long used by respondents

Coping Strategies	Period when used by respondent			How long strategy is used by respondent			
	Percentage of respondent involved			Percentage of respondent involved			
	Before drought	During drought	After drought	1 month	>1 month	1 year	>1 year
Increased livestock and livestock product sales	79.2	16.7	4.2	21.7	69.6	8.7	0
Old/weak livestock slaughtered for consumption	0	100	0	33.3	58.3	4.2	4.2
Labour migration to towns	4.8	90.5	4.8	15	65	5	15
Household splitting (e.g. sending children to relatives)	9.1	77.3	13.6	22.2	72.2	0	5.6
Seeking farms/employment	62.5	18.8	18.8	21.4	71.4	7.1	0
Opportunity to do so e.g. selling bush products and labour	14.3	42.9	42.9	21.1	68.4	5.3	5.3
Increased bush/wild product collection and sale	38.9	55.6	5.6	26.3	63.2	5.3	5.3
Livestock migration/herd splitting	8	88	4	9.1	77.3	4.5	9.1
Minimization of food consumption, reduction of meals and expenses	0	95.2	4.8	33.3	57.1	4.8	4.8
Reduction of gifts to the poor by richer households	0	78.6	21.4	8.3	83.3	8.3	0
Increased wild food consumption	20	73.3	6.7	25	62.5	0	12.5
Seeking relief assistance	4.2	91.7	4.2	14.3	19	9.5	57.1
Grain/fodder storage (mainly for wealthier households)	73.3	13.3	13.3	23.5	64.7	0	11.8
Social support systems (social alliances e.g. stock friendship)	31.2	50	18.8	22.2	66.7	5.6	5.6
Making ghee for the dry season	78.6	7.1	14.3	7.1	64.3	21.4	7.1
Increase of pack animals (draught animals e.g. donkeys)	100	0	0	21.4	7.1	7.1	64.3
Increase of fodder production and conservation to replace lost access to dry season grazing areas	86.7	0	13.3	0	73.3	26.7	0
Development and sustaining of breeding herds and sale of other stock to increase resilience	53.8	0	46.2	7.1	35.7	28.6	28.6

Source*:* Author compilation

5.3.4 Constraints to adaptation and coping strategies

The desired adaptation strategies proposed by majority of respondents include establishing strategic livestock feed reserves, irrigation farming, development of water sources and insurance for livestock, and saving schemes. Majority of respondents also expressed interest in establishing grain and fodder storage facilities, improved livestock breeds, making of livestock products such as Ghee for sale during dry seasons and increasing their herd size. The adaptation and coping strategies desired by the households are not without constraints. Table 5.5 documents contraints to adaptation and option to address the constraints. The respondents resported a number of limitations to their strategies, they include inadequate cash income and capital (46.2%), insecurity (50.8%), lack of affordable credit facilities and access (42%), illitracy and lack of technical knowledge (25%), inadequate markets (10%) and lack of inputs and equipment for agricultural practises (22%).

Further probing with FGDs participants revealed that some of these desired strategies like irrigation farming, development of water sources and insurance for assets require greater initial investment capital beyond the reach of many households. Similarly, the result indicates that while many households are interested in grain and fodder storage facilities, few would be interested in investing in these facilities bacause of pasture scarcity in the study area. While improved livestock breeds were mentioned as a desired effective adaptation measure to drought, access to livestock breeds and suitable veterinary services are problematic ,because of economic, social and infrastructal challenges in Turkana.

Insecurity and conflicts associated with livestock raids, is also a major constriant to some of the desired adaptation and coping responses in the study area. A study by Schilling *et al.* (2012) revealed that violent conflicts in Turkana if not managed is likely to undermine the gains made so far in supporting the adaptation programme in the area (Scheffran *et al.* 2014). In addition, the respondents indicated that water and pastures resources can only be accessed in areas without insecurity. More emphasizis on peace building initiativesis therefore needed in conflict hot spots along the borders of Turkana for effective adaptation stratagies. Similary, investment in education to improve literacy levels which is a major constraint to desired adaptations are key in addressing cyclic drought vulnerability in the area. Furthermore, the respondents highlighted the crutial role of local governance and institutions, political leadership and structures in improving markets access and for upholding the rule of law in Turkana. Consistent with the survey results, lack of affordable credit facilities access was frequently mentioned by FGDs respondents as the most significant constraint to desired adaptation and coping strategies identified. Results show that credit and banking facilities are only found in Lokichiggio and Lodwar town, which according to the households are only accessible to established business community and few livestock traders. Banking based on mobile phones is increasingly becoming a common and well-developed service in the area. Result showed that households are slowly embracing mobile phones for receiving cash remittences through the M-pesa system from relatives in urban centres. However, it is so far not widely used by many respondents because of the poor network coverage in Turkana.

The majority of constraints to adaptation and coping strategies are driven by the low level of development in Turkana which in turn is the result of a long history of political and socio-economic marginalization by the central government (Schilling and Remling 2011). In October 2012, the Government of Kenya adopted the National Policy for the Sustainable Development of Northern Kenya and Other Arid Lands. The policy is an important document for three reasons. First, it acknowledges marginalisation and misperceptions of pastoralism by the government. "Pastoralists are among the groups most marginalised from socio-economic services and infrastructure"(ASAL Policy 2012, p. 5). Second, the policy expresses a clear shift in perception towards recognising "the strengths of pastoralism and […] the contribution of pastoralism to food security, environmental stewardship, and economic growth"(ibid.). And third, the policy identifies critical deficiencies and measures to address them. While privileging the role of traditional pastoral governance systems, the policy advocates for strengthening the national integration, cohesion and equity by improving infrastructure, human capital, security and rule of law (Odhiambo 2013). The policy therefore is promising in reducing the marginalization of pastoral communities and constraintst to climate adaptation.

Table 5.5 Effects of climate change on key adaptation strategies and options for addressing the constraints

Adaptation strategies	Effects of climate variability and change	Constraints to adaptations	Options of dealing with constraints
i) Mobility	Water and pasture resources scarcity (Nkedianye *et al*. 2011).	Conflicts and privatization of communal lands	Peace building, strengthen local institution
ii) Diversification of livelihoods	Rangeland degradation, disruption by extreme events (Bryan *et al.* 2013)	Weak asset base, lack of financial resources and technological know how	Avail off-farm opportunities to rural communities
iii) Sending children to school to acquire education and trainings	Displacement, impact on food supply, diseases outbreaks	Poor access to academic institutions, and health services	Mobile schools
iv) Diversification of herd composition and species	Shift of rangeland herbaceous biomass to woody vegetation (Angassa and Oba 2007)	Decrease in cattle, high financial inputs	Invest in livestock species heterogeneity
v) Livestock off-take	Heat stress, and low productivity (Schultz *et al.* 2013)	Poor market infrastructures, low livestock prices	Develop livestock infrastructure – markets, veterinary services etc.

5.4 Conclusions

Majority of the pastoralists are already taking measures to protect their lives and livelihoods against increasing drought events in Turkana. However, many are facing considerable challenges in their adaptation and coping strategies, with few of them able to withstand impact of frequent droughts in the study area. The existing opportunities for household long-term adaptation strategies to drought appear to be constrained by a number of socio-economic, political changes and deteriorating ecological conditions. For example, violent conflicts, lack of affordable credit facilities and financial services, limited access to markets, changing land tenure and poor infrastructure. In addition, there are some indications that access to veterinary services, degradation of the grazing lands and extension services are also problematic.

The government, the private sector, non-governmental organizations, and donor agencies all have important roles in strengthening the adaptation and coping strategies. In particular, it is critical to value pastoralism as a productive and sustainable adaptation strategy for Turkana's, by guaranteeing free and safe livestock mobility, improving the provision of security, access to education, markets and communication infrastructure. This should be in addition to offering affordable credit facilities, strengthening extension services, diversification of livelihoods, and enhancing livestock diversity and species for drought resilience. The recently adopted Kenya ASALs policy is a good starting point but its implementation will be critical in offering pastoralists' support required for effective adaptation and coping responses. Without significant support by the government to reduce drought risks in Turkana, including violent conflict and challenges associated with the discovery of oil, households' resilience to drought will remain a mirage. This paper concludes that pastoralism remains one of the most sustainable livelihood production systems in Turkana County with the right policies and targeted investment in identified adaptation and coping responses in the area.

CHAPTER SIX

DETERMINANTS OF PERCEPTIONS ON CLIMATE CHANGE AND ADAPTATION AMONG TURKANA PASTORALISTS IN NORTHERN KENYA

Abstract

There is a growing concern that climate variability and change, combined with other environmental, social and political pressures may overwhelm resilience of pastoral systems if local adaptation strategies are not strengthened. Understanding pastoralists' perception of and response to climatic change is necessary for sustainable adaptation strategies. Systematic and purposive sampling techniques were used to select 302 households in Turkana County of north-western Kenya. Descriptive statistics and Heckman probit model were used to analyze the data obtained from the household's interviews. The results show that majority of households' perceive rise in temperatures and rainfall variability over the past three decades. Pastoralists' perception of climate change was significantly ($p<0.05$) associated with gender of the household head, livestock ownership, herd size and access to extension services. Heckman's sample selectivity probit model revealed that factors influencing pastoralist's choices of climate change adaptation include gender and education level of the household head, household size, wealth in terms of livestock ownership, distance to markets, access to credit and extension services. We conclude that as a prerequisite for long-term commitment to household's climate resilience, policies and programmes should aim at improving these factors.

Keywords: Adaptation strategies, climate variability and change, drought, resilience, Turkana

6.1 Introduction

Perceptions of climate change particularly within dryland communities are very important in addressing adaptation to extreme climate events in sub-Saharan Africa (Fraser *et al.* 2011; Silvestri *et al.* 2012). Studies show that dryland communities' normally bear the brunt of extreme climate change and likely to be more vulnerability unless appropriate adaptation measures are put in place (Hassan and Nhemachena 2008; Rao *et al.* 2011). Future climate scenarios predict increased frequency and intensity of dry spells throughout the drylands of East Africa (Hulme *et al.* 2001; Christensen and Hewitson 2007; Below *et al.* 2010; Intergovernmental Panel on Climate Change (IPCC) 2014), with impacts projected to worsen and, threaten food security and erode climate resilience of communities. It is however, assumed that for households to decide whether to adapt or not to climate changes they must first perceive the change (Deressa et al. 2009). Thus, perception is seen as a prerequisite for adaptation (Hansen *et al.* 2004; O'Brien 2006; Thomas *et al.* 2007; Silvestri *et al.* 2012). Studies by Callaway (2004) and Fraser et al. (2011) indicate that dryland communities, especially pastoralist are vulnerable to climate induced stresses due to their low adaptive capacity and over dependence on climate sensitive livelihood activities. Their vulnerability to increasing climate change is further compounded by other socio-economic, political and ecological factors including but not limited to inadequate sources of income, limited livestock marketing opportunities, political marginalization, changing land tenure, unclear property right regimes, and breakdown of traditional social and resource governance institutions (Wasonga *et al.* 2012; Bryan *et al.* 2013). Therefore, to identify sustainable mechanisms to minimize impacts of climate change and vulnerability of the households, it is essential to have full comprehension of factors that influence perceptions of climate change and adaptation choices. Adaptation in this context refers to initiatives and measures to reduce vulnerability of human systems against actual or expected climate change effects (Intergovernmental Panel on Climate Change (IPCC), 2012). While, vulnerability denotes the capacity to be wounded, i.e., the degree to which a system is likely to experience harm due to exposure to a hazards (Turner *et al.* 2003)

A number of studies (Hassan and Nhemachenas, 2008; Lema and Majule 2009; Deressa *et al.* 2009; Speranza 2010; Fosu-Mensah *et al.* 2012) have attempted to analyze factors affecting the choice of adaptation in mixed crop-livestock farming systems in sub-Saharan Africa. However, none has paid attentions to pastoral systems in the arid and semi-arid areas of Kenya. Therefore, these previous studies findings may have little relevance to situation in the extensive livestock production systems in the region. That notwithstanding, studies by Kabubo-Mariara (2008), Roncoli *et al.* (2010), Recha (2010), Silvestri *et al*. (2012) and Bryan *et al.* (2013) have to some extent examined rural communities perceptions of climate change and adaptation strategies in Kenya. Silvestri *et al.* (2012) collected data from agro-pastoral communities in seven rural districts of Kenya and employed multi-nomial logit (MNL) model to estimate the effect of a set of explanatory variable on dependent variable involving multiple choices with unordered response categories. Similarly, Recha (2010) looked at the adaptive capacity of local communities to climate change across three agro-ecological zones of Tharaka district in Kenya, and largely assumed that all the households interviewed perceived and were impacted by climate change. A study by Bryan *et al.* (2013) in various agro-ecological zones of Kenya focused on ongoing adaptation measures and factors influencing farmers' decision to adapt to climate change. Overall, these studies revealed that households in agro-pastoral systems indeed perceive climate to be changing and are adapting to reduce the adverse impacts of extreme climate events. The conclusions from these studies are vital for designing adaptation strategies that deal with impacts of climate change and variability on similar production systems.

This study builds on previous research findings with a view to highlight the determinants of pastoralists' perception of and adaptation to climate change at a micro-level in Turkana County of north-western Kenya. It is acknowledged that millions of pastoralists use various adaptation and flexible risk management strategies to manage the often harsh and unpredictable environment under which they reside (Mworia and Kinyamario, 2008; Opiyo *et al.* 2011). The adaptation strategies historically used by pastoralists include but not limited to the following; livestock migration to access better pasture and water, keeping varying species mix to take advantage of the heterogeneous nature of a disequilibrium environment, and diversifying economic strategies to crop production, wage labour, ecotourism and beekeeping, among others (Swift *et al.* 2001, Mworia and Kinyamario, 2008; Eriksen and Lind 2009). However, some of these strategies have been weakened or collapsed over the years. Studies by Hendrickson et al. (1996), Lamprey and Reid (2004), and Nkedianye *et al.* (2011) indicate that the collapse to some of these adaptation strategies results from changing socio-demographic, economic, ecological and environmental factors, all exacerbated by extreme weather events. Füssel (2007) argued that adaptation can greatly reduce households' vulnerability to climate change by making them better able to adjust to extreme climate events, moderate potential damages, and be able to cope with adverse consequences. Other studies (Below *et al.* 2010; Fraser *et al.* 2011; Bryan *et al.* 2013) revealed that for informed decision making, sustainable climate change adaptation require documenting information relevant to multiple stakeholders, including individual households, policymakers, extension agents, development agencies, researchers, pastoralists and the private sector.

This study aimed to identify determinants of households' perception of and adaptation to climate change in Turkana County of north-western Kenya. Understanding the local context and the perception of households are critical in addressing adaptation to climate change in the drylands. It is hypothesized that different socio-economic and environmental factors influence households' perceptions of and adaptation to climate change.

6.2 Methodology

6.2.1 Study area

The detailed description of the study area and research design is found on Chapter Three of the Thesis.

6.2.2 Data collection

In order to obtain a detailed understanding of pastoralists' perceptions and adaptations to climate change, multiple data collection techniques were used which include household interviews, focus group discussion, and key informant interviews as described in Chapter Three section 3.2 of the Thesis.

Empirical model

Data analysis involved a two-stage process proposed by Maddison (2006). The first stage involves the question of whether the respondents perceived climate change or not (particularly on change in temperature, and rainfall amount, frequency and length of season), while the second stage is about whether the respondents adapted to climate change conditional on the first response that they perceived climate change, or otherwise. This leads to a sample selectivity problem, since only those who perceive climate change could adapt. Therefore, Heckman's sample selectivity probit model is used to correct for this selection bias (Heckman 1976; Maddison 2006; Deressa *et al.* 2009).

According to Heckman (1976), the probit model for sample selection assumes that there exists an underlying relationship which consists of the latent equation given by:

$$y_j^* = x_j\beta + u_{1j} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

such that we observe only the binary outcome given by the probit model as:

$$y_j^{Probit} = \ y_j^* > 0 \ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

The dependent variable is observed only if *j* is observed in the selection equation

$$y_j^{Select\ t} = \ z_j\delta + \ u_{2,j} > 0 \ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

$$u_1 \sim N\ \ 0,1$$
$$u_2 \sim N\ \ 0,1$$
$$Corr\ \ u_1, u_2\ \ = \ \rho$$

Where, *x* is a *k*- vector of regressors (explanatory variable which include different factors hypothesized to influence adaptation strategies), *z* is an *m* vector of repressors (explanatory variables which include different factors hypothesized to affect perception), u_1 and u_2 are error terms. Thus, the first stage of the Heckman's two-step model is the selection model (Equation 3), which represents the perception of change in climate. The second stage is the outcome model (Equation 1), which present whether the pastoralists adapted to climate change, and is conditional on the first stage that they perceived a change in climate. The perceptions regarding climate change was captured in terms of temperature and rainfall increase, decrease, variability or no change. To take care of the bias introduced due to self-selection rising from not perceiving climate change in the area, Heckman selection model was fitted and tested for its appropriateness over the standard probit model.

When $\rho \neq 0$, standard probit techniques applied to equation (1) yield biased results. Thus, the Heckman probit (heckprob) provides consistent, asymptotically efficient estimates for all parameters in such models (StataCorp 2003). The Heckman probit selection model was, therefore, employed to analyse pastoralists' perception of climate change and adaptation in this study. The method was criticized in the literature because of its sensitivity to the normality assumption (Marchenko and Genton 2012). However, despite Heckman selection model limitations, it allows the analysis of decisions across more than two classes, and allowing the determination of choice probabilities for different categories (Deressa *et al.* 2009; Marchenko and Genton 2012).

Explanatory Variables

The choice of the hypothesized explanatory variables used in the model was based on a comprehensive review of literature on climate change adaptation and data availability (Maddison 2006; Deressa *et al.* 2009; Silvestri *et al.* 2012). The independent variables hypothesized as affecting pastoralist's perception of climatic change and to whether they adapted based on their own perception are given in Table 6.1. The explanatory variables included household characteristics such as gender, education, age of the household head, household size, farm and non-farm income, and livestock ownership, access to extension services, livestock ownership and production, information on climate, access to credit, social networks and remittances.

This study hypothesized that farming experience of household head increases the probability of adaptation to climate change. Previous studies indicate that there is a positive correlation between age of the household head and farming experience (Deressa *et al.* 2009; Silvestri *et al.* 2012). Evidence from various sources indicates that there is a positive relationship between education level of the household head and adaptation to climate change (Maddison 2006). High level of education is associated with access to information on markets and early warning information (Norris and Batie 1987; Bryan *et al.* 2013). Therefore, it was hypothesized that household heads with a higher levels of education were more likely to adapt to climate change. Nhemachena and Hassan (2007) observed that female-headed households are more likely to take up climate change adaptation methods than the male headed households. This is more likely because women are responsible for most of the household duties in pastoral areas and therefore have greater experience and likely to access information on various adaptation practices. The possibilities of households to diversify and expand livelihood sources as adaption to climate change require financial well-being. Therefore, households with higher farm and non-farm income sources are likely to adapt better to climate change than their counterparts with lower incomes sources. Kelly and Adger (1999) demonstrate households with higher levels of household income are better able to manage climate change impacts and loss.

Table 6.1 Description of model variables

Dependent Variables Descriptions	Units	HH who perceived climate change (%)	HH who didn't perceived climate change (%)
Climate change perception (dummy: takes the value of 1 if perceived and 0 otherwise)	1 = yes, 0 = no	96.7	3.31
Independent Variable	Units	Mean	Std Error
Gender of household head	1 =Male, 0 = female	0.49	0.02
Education of household head	Years in Schools		
	No formal education	0.80	0.02
	Primary education	0.16	0.02
	Secondary education	0.04	0.01
	Tertiary education	0.00	_
Age of household head	Categorical		
	18-30yrs	0.17	0.02
	31-50yrs	0.50	0.03
	51+yrs	0.24	0.02
Household size	Numbers		
	1-5 persons	0.35	0.03
	6-10 persons	0.49	0.03
	11-15 persons	0.12	0.02
	> 16 years	0.36	0.01
On farm income	1= yes, 0 = no	0.35	0.03
Off farm income	1= yes, 0 = no	0.42	0.04
Livestock ownership	1 = yes, 0 = no	0.80	0.02
Lactating livestock	1= yes, 0 = no	0.27	0.03
Herd size	Continuous	61.53	8.71
Extension services	1 = yes, 0 = no	0.46	0.03
Distance to markets	Categorical		
	<1 km	0.11	0.02
	1-2km	0.06	0.01
	3-5km	0.13	0.02
	6-10km	0.31	0.03
	>10km	0.39	0.03
Access to climate information	1 = yes, 0 = no	0.25	0.02
Access to credit	1= yes, 0 = no	0.22	0.02
Social network	1= yes, 0 = no	0.74	0.03
Remittances	1= yes, 0 = no	0.42	0.03

HH – households

Livestock plays a very important role by serving as a social, economic or financial and cultural asset for most pastoral communities (Megersa *et al.* 2014). Thus, for this study, livestock ownership is hypothesized to increase adaptation to climate variability and change. Studies indicate that herd size has positive effects on adaptation to climate change (Naess and Bardsen, 2013). However, because large herd sizes are associated with greater wealth in pastoral communities, it is postulated to increase adaptation to climate change. Similarly, extension services represent access to the information required to make the decision to adapt to climate change. Various studies (Deressa *et al.* 2009; Ndambiri *et al.* 2012), have reported that access to extension services and information facilitates decision making with regard to climate change adaptation. Access to affordable credit facilities eases cash constraints and allows households to invest in production inputs. Thus, it was hypothesized that there is a positive relationship between access of credit and adaptation to climate change. Previous studies by Njuki *et al.* (2008) and Tumbo *et al*. (2013) show that social network are important and include relatives, friends and community organizations. In pastoral systems, social networks provide strong bonds within a social group, a sense of identity and linkages to other outside groups that can bring in additional resources during shocks and stresses (Magnan *et al*. 2013). Therefore, it was hypothesized that social networks positively influence adaptation to climate change.

6.2.3 Statistical analysis

The quantitative data collected were analysed using STATA software (version 9.0) from StataCorp LP (StataCorp 2003). Descriptive statistics were run to give frequencies and percentages of households' socio-economic characteristics for presentations. The Heckman probit model was used to analyze data obtained from the household's interviews to investigate determinants of pastoralists' perceptions of and adaptation to climate change at a household level.

6.3 Results and Discussion

6.3.1 Socio-economic characteristics of the respondents

The results showed that 50.7% of the respondents were female whereas male respondents accounted for 49.3%. Majority of the respondents were within the ages between 31 and 51 years and above. In the study area, households live in clustered homesteads with an average family size of six persons. This is higher than the national household average of 5.1 persons (Kenya

National Bureau of Statistics 2013). The study area is dominated by adult household heads with no formal education and low literacy level (< 20%). The majority of the respondents (70.53%) were married, approximately 26.5% were either widowed or divorced, and 3% of the respondents were singles who had never been married.

The finding shows that pastoralism is the main source of livelihood in the study area, and that most respondents derive their income from livestock production (79.8%). Other farm activities households engage in were crop production, mixed and poultry production. Most livestock species kept by households were goats, sheep, camels, cattle and donkey. The results suggest a shift in herd composition in an attempt to adapt to changing climatic conditions since goats and camels were increasing in numbers and are known to be more resilient to drought compared to cattle (Toulmin 1996; Kagunyu and Wanjohi 2014). However, some of the respondents also engaged in off-farm activities. Table 6.2 presents the average monthly household income sources in the study area. Since majority of the households earn their income from climate sensitive activities, they are likely to be affected by frequent drought events in the study area. The climate change effects are exacerbated by other climate induced shocks and stresses such as livestock diseases, for example *peste des petit ruminants* (PPR) and floods. Frequent hazards means that pastoralist do not have enough food for better part of the year. In order to cope with these situations, households are engaging in wage labour, receiving cash remittances from relatives and government, engaging in sale of charcoal and firewood, and are also venturing in other small businesses enterprises.

Table 6.2 Average monthly household income sources

On Farm		Off/Non-farm based	
Source	Income in KES[a]	Source	Income in KES[a]
Livestock sales	6,470 (±825.90)	Small business enterprises	3,879 (±845.30)
Crop sales	1,425 (±286.10)	Wage employment	3,000 (±511.60)
Crop & livestock sales	13,333(±3,333.30)	Artisan activities	18,250 (±14,061.60)
Poultry sales	500 (±173.02)	Salaried employment	19,250 (±10,974.40)
		Charcoal production	1,733 (±143.60)

[a]Exchange rate for June 2012, KE- Kenya Shillings (85 KES = 1 US $)

6.3.2 Households' perceptions of climate change

Majority (96.7%) of the respondents perceived various changes in climatic factors in the study area (Table 6.1). The perception of these changes, however, varies between gender. A high proportion of both males (96%) and females (97%) experienced changes in temperature and rainfall amount, frequency and length of rainy season over the last three decades. Most of the respondents (55.5%) perceived increasing temperature, while only 24% observed a decrease in temperature (Table 6.3). The respondents' perceptions of rising temperature are in tandem with actual climate data recorded in the nearby meteorological stations in the study area. This implies that households could be highly valuable key informants on studies related to climate change. The valuable knowledge of the pastoralist could also be used for climatic forecasting. Temperature increases are known to have a significant impact on water availability and pasture resources, thus likely to exacerbate vulnerability of the pastoralists (Hererro *et al.* 2010). The Global climate models for the region indicate that by the year 2100, climate change will increase temperatures by about 4°C (Kabubo-Mariara 2008).

With regard to rainfall amount, frequency and length of rainy season, households specified various changes they had perceived in the study area. Overall, 42.1% of the respondents perceived rainfall amounts to be decreasing, with 36.3% indicating that rainfall had become highly variable and more erratic (Table 6.3). These observations were consistent across the entire study area. The respondents also noted decreasing rainfall frequency (34.9%) and length of the rainfall seasons (72.3%) over the past 30 years. From the focus group discussions and interviews with key informants, majority confirmed a decrease in the number of rain days coupled with frequent droughts in 1990 to 1995, 1999 to 2000, 2008 to 2009 and 2010 to 2011. The main concern expressed by the respondents was about greater variability and seasonal changes, which hindered their ability to predict rainfall patterns and plan their grazing managements accordingly. In addition, many respondents reported that the shorter rainy seasons has led to longer dry periods in between seasons, which results in higher pressure on the available pasture resources. These observations by respondents correspond with reports from weather stations that revealed high level of variability of rainfall distribution over the past three decades in the arid and semi-arid environments of Kenya (Galvin *et al.* 2001; Shisanya *et al.* 2011). Figure 6.1 show standardized precipitation index (SPI) and temperature variability (Tmax) between 1979 and 2012 in the study area.

Table 6.3 Pastoralists' perception of rainfall amount, frequency and length of season for the past 30 years

	Temperature	Rainfall amount	Rainfall frequency		Length of rainy season	
Description	% distribution	% distribution	Description	% distribution	Description	% distribution
Increasing	55.48	4.45	Increasing	34.93	Decreased	72.26
Decreasing	23.97	42.12	Decreasing	32.88	Increased	9.25
No change	0.34	10.62	No change	10.62	No change	4.79
Un predictable	16.44	36.30	Don't Know	21.58	Don't Know	13.70
Don't know	10.0	6.51				

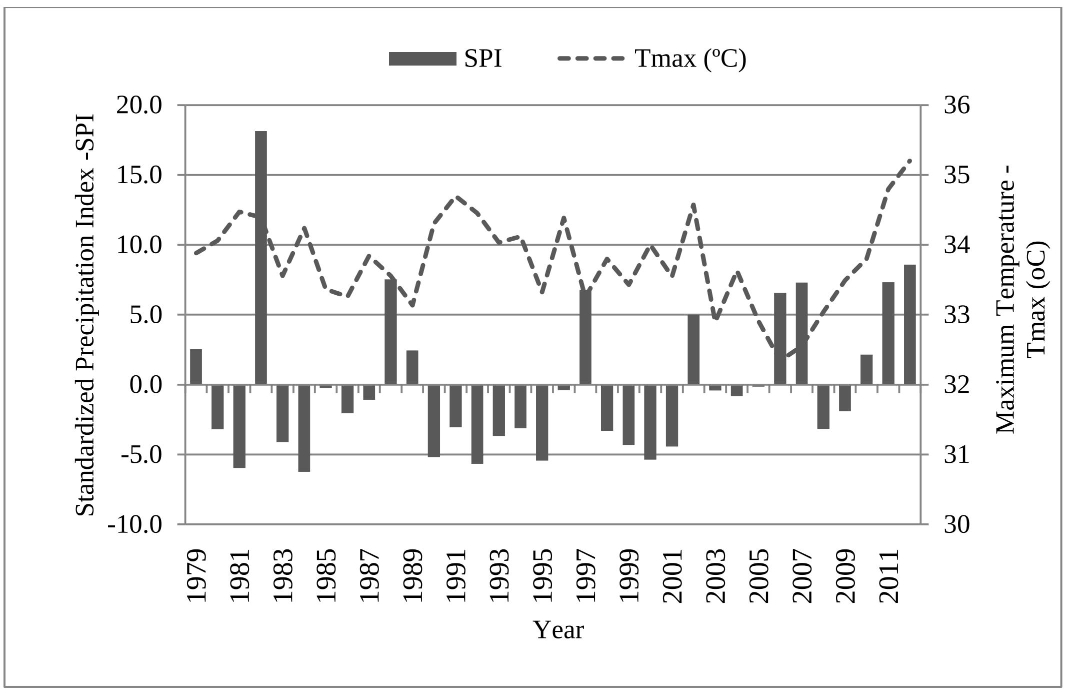


Figure 6.1 Standardized precipitation index and temperature variability between 1979 and 2012 in Lodwar

6.3.3 Factors influencing perception of climate change by households

The results of selection model analyzing factors affecting perception of climate change are presented in Table 6.4. In the analysis, gender of the household head, livestock ownership and herd size, access to extension services were found to influence households' perception of climate change. From the socio-economic factors examined, the results suggest that female-headed households are more likely to perceive a change in climate such as increase in temperature and decrease in the length of rainy seasons than male-headed households. The fact that female-headed households are more likely to perceive changes may be because they are responsible for most of the household duties. A number of studies in Africa have shown that female-headed households are more likely to perceive climate change (Nhemachena and Hassan 2007; Silvestri *et al.* 2012). The possible reason for this observation is that in most rural smallholder farming communities, men are more often based in urban centers, and much of the agricultural work is done by women. Therefore, women have more farming experience and information on various management practices and challenges experienced. Livestock ownership and herd size has a positive and significant influence on the likelihood that households perceive climate change. In addition, this study revealed that access to extension services significantly increases the likelihood that households perceive climate change. Studies by Deressa *et al.* (2009) similarly reported that access to extension services play an important role in the availability and flow of information critical for climate perception. Overall, the study confirms our hypothesis that different household characteristics and socio-economic factors affect the abilities of pastoralists to perceive climate change.

6.3.4 Determinants of households' adaptation to climate change

The results of the outcome model (Table 6.4), which analyzes factors affecting adaptation indicate that that most of the explanatory variables affected the probability of adaptation. Explanatory variables that positively and significantly influenced adaptation to climate change include gender of the household head, age and education level of the household head, household size, access to credit, cash remittance, farm-based income, distance to livestock market and access to extension services, livestock ownership and herd size.

The findings show that gender of household head significantly influenced the likelihood that a household took up the climate change adaptation strategies. The female-headed households were more likely to take up climate change adaptation since they are responsible for most of the household welfare activities and have better experience on various farm based production practices in the study area. In contrast, studies in the Nile basin of Ethiopia indicate that male-headed households adapt more readily to climate change (Hassan and Nhemachena 2008). Educational level of household head was found to be significant determinants of adaptation to climate change. The study suggest that heads with higher level of education are likely to have better level of planning, access and understanding of early warning information for effective climate change adaptation. Thus strengthening education sector could be one of the key areas for building climate change resilience of the households in the study area. The average size of household had a positive and significant influence on the likelihood that pastoralist adapt to climate change. Larger households are associated with higher labour endowments, which would enable the household to accomplish various production tasks (Nhemachena and Hassan 2007; Silvestri *et al*. 2012). This study suggest that access to affordable credit facilities is likely to eases cash constraints and allows households to invest in production inputs for climate change adaptation. Similarly, cash transfers and remittance from relatives and friends are important determinants of climate change adaptation and normally allow households to have additional cash for livelihood diversification (Bryan *et al.* 2009). Farm income has a positive and significant impact on the probability that pastoralist adapt to climate change. Given the climatic-induced challenges facing households in the drylands, income from livestock has previously been reported to play an important role for enhancing climate change adaptation (Rao *et al.* 2011). Other farm based income activities include small scale sorghum production and Aloe cultivation. In Oropoi, for example, majority of the households plant *Aloe turkanensis* and *A. scabrifolia* that is exploited and sold locally for various uses.

The result of this study show that distance to markets significantly influences the likelihood of household adaptation to climate change. This is possible because access to markets give the household opportunity to purchase inputs and sell their goods. Previous studies by Maddison (2007), and Kirkbride and Grahn (2008) had indicated that farmers' adaptation among livestock producers is hindered by the absence of markets, particularly for the purchase of additional animal or new breeds or species. In contrast, key informant interviews in this study revealed that most households close to market centers in Lokichoggio, Kakuma, or Lodwar were unlikely to adapt to climate change compared with their counter parts in remote rural locations. The cash obtained is quickly dissipated by household needs and expensive peri-urban lifestyle without re-investing into productive risk management enterprises. Access to information on climate change through extension agents are likely to creates awareness and favorable condition for households to make rational adaptation decision that are suitable under climate change.

In addition, results of this study show that ownership of livestock, herd size and lactating herd has a positive and significant impact on the likelihood that households adapt to climate change. Livestock ownership is a sign of wealth to pastoralist (Watson and van Binsbergen 2008). The possession of livestock plays an important role as a store of wealth among pastoralist and also provides economic, social-cultural values required for adaptation. Thus, the larger the herd size a household own, the more likely that they have financial resources to engage in creating other income sources for climate change adaptation. Further results show that lactating herd positively influenced climate change adaptation. This is probably because milk obtained from lactating herd allows households to feed themselves and sell surplus to meet other family needs during extreme climate events. The livestock kept for milk by the Turkana's are cattle, goats and camels. Previous studies (McPeak and Little 2005; Fratkin *et al.* 2011) indicate that lactating herds are essential resources for adapting to climate stresses in the arid and semi-arid lands-ASALs.

Table 6.4 Parameter estimates from the Heckman's selection Model

	Adaptation model			Selection Model		
Explanatory variables	Par. estimate	S.E	P-Value	Par. estimate	S.E	P-Value
Gender	-0.025	0.038	<0.001**	0.444	0.212	0.036**
Age (years)						
18-30						
31-50	0.089	0.051	0.081*	-0.045	0.210	0.832
50+	-0.008	0.057	0.896	0.180	0.300	0.549
Education level						
No formal						
Primary	0.066	0.053	0.211	0.158	0.246	0.522
Secondary, Tertiary & University	0.229	0.117	0.050**	0.258	0.487	0.596
Livestock ownership	0.030	0.057	0.062*	-0.713	0.364	0.050**
Social networks	0.046	0.036	0.198			
Access to climate information	-0.036	0.042	0.395	-0.077	0.241	0.750
Household size (# persons)						
1-5 persons						
6-10 persons	-0.020	0.040	0.611			
11-15 persons	0.124	0.056	0.027**			
>16 persons	0.072	0.097	0.460			
Credit facility	0.099	0.033	0.002**			
Remittance	0.053	0.029	0.074*			
On farm income	0.090	0.045	0.045**	-0.124	0.239	0.603
Off farm income	0.018	0.055	0.746			
Distance to livestock market						
< 1 Km						
1-2 Km	0.165	0.043	<0.001**			
3-5 Km	0.133	0.042	0.001**			
6-10 Km	0.235	0.051	<0.001**			
>10 Km	0.206	0.051	<0.001**			
Access to extension services	0.150	0.038	<0.001**	0.801	0.195	<0.001**
Lactating livestock ownership	0.066	0.039	0.096*			
Herd size	0.042	0.033	0.005**	0.526	0.234	0.019**
Constant	0.694	0.103	<0.001**	1.175	0.500	0.019**

Significant 10% (*p<0.1); 5% (**p<0.05)

6.4 Conclusion and Policy Implications

This study examines determinants of pastoralists' perception on climate change and adaptation choices in Turkana County of north-western Kenya. Pastoralists' perceptions of climatic change are in line with climatic data records from the nearby meteorological stations. The increasing temperatures and variability in rainfall documented by climatologists conform closely to the view held by most respondents in the study area. This implies that pastoralists could be highly valuable key informants on study related to climate change. The findings demonstrate that households with access to extension services are likely to perceive climate changes because extension services provide information and create awareness. Given the inadequate extension services in the Turkana County, improving the knowledge and skills of extension agents on climate change and adaptation strategies is crucial. Further, results suggest that an investment in education systems, programmes on women empowerment, pro-poor policies on access to affordable credit facilities, social protection schemes for the vulnerable, and access to markets especially for livestock are likely to enhance pastoralist's climate change adaptations. However, most of the factors identified as influencing perception of and adaptation to climate change are directly related to pastoralists' socio-economic characteristics in the study area. Therefore, future studies could explore biophysical variables as well such as environmental setting, soil type, vegetation, and temperature and rainfall amount received.

CHAPTER SEVEN

MEASURING HOUSEHOLD VULNERABILITY TO CLIMATE-INDUCED STRESSES IN PASTORAL RANGELANDS OF KENYA: IMPLICATIONS FOR RESILIENCE PROGRAMMING

Abstract

This study uses statistical and econometric tools to measure households' vulnerability in pastoral rangelands of Kenya. It considered 27 socio-economic and biophysical indicators obtained from 302 households' in-depth interviews to reflect climate vulnerability components: adaptive capacity, exposure and sensitivity. The theoretical framework used combines exposure and sensitivity to produce potential impact, which was then compared with adaptive capacity in order to generate an overall measure of vulnerability. Principal component analysis (PCA) was used to develop weights for different indicators and produce a household vulnerability index (HVI) so as to classify households according to their level of vulnerability. In order to understand the determinants of vulnerability to climate-induced stresses, an ordered probit model was employed with predictor variables. The results show that 27% of households were highly vulnerable, 44% were moderately vulnerable and 29% of households were less vulnerable to climate-induced stresses. Factor estimates of the probit model further revealed that the main determinants of pastoral vulnerability are sex of household head, age of household head, number of dependents, marital status, social linkages, access to extension services and early warning information, complementary source of income, herd size and diversity, herd structure, herd mobility, distance to markets, employment status, coping strategies and access to credit. Therefore, policies that address these determinants of vulnerability with emphasis on women's empowerment, education and income diversifications are likely to enhance resilience of pastoral households.

Key words: Climate change, pastoralists, principal component analysis (PCA), resilience, vulnerability

7.1 Introduction

Vulnerability, commonly defined as the propensity or predisposition to be adversely affected, has been studied as a composite of adaptive capacity, sensitivity and exposure to hazards (Adger and Kelly 1999; Kelly and Adger 2000; McCarthy *et al.* 2001; Intergovernmental Panel on Climate Change IPCC 2001; Adger 2006; Fussel 2007; Paavola 2008; Yuga *et al.* 2010). Adaptive capacity is the ability of people to cope with or adjust to the changing context and is explained by socio-economic indicators. Sensitivity is the ability of a system to be affected, and exposure is the incidences of events (Kasperson *et al.* 1995; Adger 2006; Paavola 2008). Vulnerability is thus comprised of risks or a chain of risky events that households confront in pursuit of their livelihoods, the sensitivity of livelihood to these risks, the response or options that households have for managing these risks and finally the outcomes that describe the loss in well-being (Turner *et al.* 2003).

On the other hand, resilience is seen as the ability to self-organize, learn, and adapt to risk hazards (Carpenter *et al.* 2001; Turner *et al.* 2003). United Nations International Strategy for Disaster Reduction (UNISDR 2009) define resilience as the transformative process of a household or community exposed to hazards to resist, absorb, accommodate, and recover from hazards timely and efficiently. Turner *et al.* (2003) and Gallopin (2006) define hazards as threats to a system and comprised of stressors. For simplicity, the term stress is used in this study to denote a continuous or slowly increasing pressure (in this case drought), commonly within the range of normal variability. However, over the last decades, most of the scientific literature and discourses on vulnerability has concentrated on contributing to theoretical insights or measurements at a regional or national scale, with selected indicators for each region, and identifying resilience building strategies that have implication for national and regional planning (Brooks *et al.* 2005; Fussel 2007; Hinkel 2011). Yet, micro-level vulnerability analysis is an essential pre-requisite for local-level planning and prioritization of resilience planning and strategies especially among the natural resource dependent communities perceived to be at risk to projected climate variability and changes (Callaway 2004; Fraser *et al.* 2011).While there is no superior scale of climate vulnerability analysis, recent studies by Yuga *et al.* (2010) and Marshall *et al.* (2014) have confirmed that micro-level analyses have hitherto largely been overlooked in favour of ecosystem-scale studies of biophysical vulnerability.

As observed by Deressa *et al.* (2008), climate change vulnerability analysis ranges from local or household level (Adger 1999) to the global level (Brooks *et al.* 2005; Intergovernmental Panel on Climate Change IPCC 2014). However, the choice of scale is dictated by the objectives, methodologies and data availability. The present study focused on household-level vulnerability analysis. After all, it is by understanding, planning for, and adapting to a changing climate that individual households can take advantage of opportunities to reduce risks associated with climate induced stresses (Madu 2012). Similarly, Klein *et al.* (2007) observed that vulnerability analysis to climate change is needed at the level that would enable policy makers to tackle climate change challenges with the precision that is necessary, particularly in the arid and semi-arid regions of Africa. Previous studies by Brook *et al.* (2005) and Intergovernmental Panel on Climate Change IPCC (2012) concluded that the majority of households are particularly vulnerable to the impacts of climate change in the arid and semi-arid regions. Although the causes of such vulnerability are multi-dimensional, they are primarily due to widespread poverty, food insecurity, recurrent droughts, land degradation, inequitable land distribution, and overdependence on rain-fed agriculture (Notenbaert *et al.* 2013; Lo´pez-Carr *et al.* 2014). Some of the other common factors also postulated to determine adaptive capacity, and therefore influence vulnerability at the household level include; access to resources, markets and infrastructure; household structure, gender, education and age; farm size; income and income diversity; access to community-based organizations, information, credit facilities, savings and loans; and health status among others. Stringer *et al.* (2009) argued that though all households in a community are exposed to risks associated with climate change and could potentially be rendered vulnerable; the poorer households are the most at risk of adverse impacts of climate variability and change. That notwithstanding, the proportion of households vulnerable to extreme weather events is perceived to be increasing in arid environments of eastern Africa, especially in Kenya, and there is an uncertain degree to which the population or the system is becoming susceptible and unable to cope with hazards and stresses, including the effects of climate change.

In Kenya, there is consensus that projected climate change will worsen food security, mainly through increased extremes and temporal or spatial shifts (Eriksen and O'Brien 2007; Herrero *et al.* 2010; Sherwood 2013). In fact, there is considerable potential impact of these global drivers of change on production systems and resource-poor households who depend on them. Studies by Kabubo-Mariara (2009) and Silvestri *et al.* (2012) revealed that extreme weather events such as prolonged dry spells and intense rainfall are already affecting rural household communities in parts of arid and semi-arid lands (ASAL) of Kenya. At present, nearly 30% of the total human population resides in the ASALs, which cover approximately 88% of the country's land mass, and hold almost 70% of the total national livestock herd. However, large proportions of pastoralist who reside in ASALs are believed to be at risk of food production deficit, with a potential declines in pasture and water availability (Opiyo *et al.* 2011), all exacerbated by extreme climate events. Hence, the purpose of this paper is to identify the determinant of vulnerability and measures micro-level vulnerability of a pastoralist in arid rangelands of Kenya. The vital information that is obtained from household-level vulnerability analysis is presently lacking in national and regional level assessments. Deressa *et al.* (2008), Pearson *et al.* (2008), and Sherwood (2013) show that vulnerability contexts are diverse for different multiple spatial scale, and therefore this approach can help to contextualize how climate variability and change affect pastoralist livelihoods.

This study was thus carried out to investigate households' vulnerability to climate variability and change to climate-induced stresses in pastoralist rangelands of Kenya. The study identifies some of the determining factors for vulnerability to climate induced stresses based on certain household social, economic and environmental (biophysical) characteristics. The household was selected as the main unit of analysis because major decisions about adaptation to climate induced stresses and livelihood processes are taken at the household level (Thomas 2008). Nevertheless, households are connected to the wider community, which can greatly influence the decision-making process in relation to the use of particular productive resources. The findings of this study can therefore be useful for targeting intervention, priority setting and resource allocations at micro-level. Complemented with studies analysing climate change impacts and findings from country-level adaptive capacity, governmental policy can be informed. At the same time, the uncertainty associated with climate change and variability demands for an approach that prepares rural households without relying on detailed climate projections. The study therefore focused on the adaptive capacity of households for wider resilience programming. Moreover, the findings could assist in resources allocation and determination of resilience investment opportunities that are likely to increase adaptive capacity of vulnerable households. The findings in particular suggest potential avenues for research that may further enhance understanding of household vulnerability to climate stresses in the arid rangelands of Kenya.

7.1.1 The study area

The detailed description of the study area and the research design is found in Chapter Three of the Thesis.

Figure 7.1 shows the annual rainfall variability of the study area. The main rainy season at local level between March 1950 and July 2012 revealed that the study area received very low and variable rain. In the past decades, the major widespread drought events were experienced in 1980 to1984, 1990 to1995, 1999 to2000, 2008 to 9 and 2010 to 2011 within the study area. The last drought crisis in the Horn of Africa is estimated to have affected over 13 million people, including 3.75 million Kenyan, especially in the ASALs (UN-OCHA 2011).

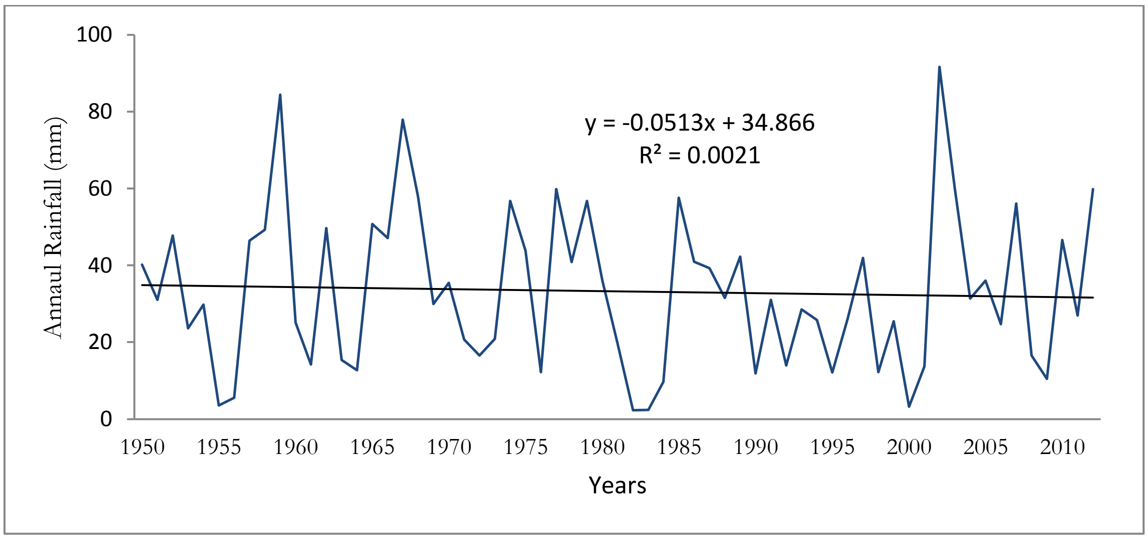


Figure 7.1 Annual rainfall variability for period 1950 to 2012 in the study area

7.2 Methods

7.2.1 Data collection

The data collection processes is described in Chapter Three section 3.2 of the Thesis. Table 7.1 shows the sampled households from each of the 10 Kraals/locations.

Table 7.1 Sampled households by Kraal

Location/Kraals	Number of households	Sampled Household	Percent of respondent
Mogila	1,536	20	6.62
Lokichoggio	1,868	9	2.98
Lopusiki	649	1	0.33
Lopwarin	277	11	3.64
Songot	459	19	6.29
Nanam	748	38	12.58
Kakuma	12,767	33	10.93
Letea	4,957	56	18.54
Kalobeyei	2,577	39	12.91
Pelekech	1,863	76	25.17

Kraal used herein to refer to a traditional pastoralists village of huts, typically enclosed by a fence.

7.2.2 Analysis of households' vulnerability

There are various ways of analysing vulnerability, namely, socio-economic, biophysical and an integrated approach, which unites both socio-economic and biophysical factors. The socio-economic vulnerability assessment approach focuses on the socio-economic and political status of individuals or groups. Individuals in a community vary in terms of education, gender, wealth, health status, access to credit, access to information and technology, formal and informal (social) capital and political power, which are responsible for variations in vulnerability levels (Füssel 2007; Deressa *et al.* 2008). Consequently, vulnerability is considered to be a starting point or a state that exists within a system before it encounters a hazard event (Kelly and Adger 2000). In this regard, vulnerability is constructed by society as a result of institutional and economic changes. The socio-economic approach focuses on identifying the adaptive capacity of individuals or communities based on their internal characteristics. One major limitation of the socio-economic approach is that it focuses only on variations within society, but in reality, societies vary not only due to socio-political factors but also because of environmental or biophysical factors. The socio-economic approach does not account for the availability of natural resource bases which have the potential to counteract the negative impacts of environmental shocks. For example, areas with easily accessible underground water can better cope with drought by utilizing this resource than areas without it (Deressa *et al.* 2008).

The second commonly used approach is biophysical that attempts to assess the level of damage that a given environmental stress causes on both social and biological systems. It is sometimes known as an impact assessment. The emphasis is on the vulnerability or degradation of biophysical conditions (Liverman 1990). This is a dominant approach employed in studies of vulnerability to natural hazards and climate variability and change (Hewitt 1995). Füssel (2007) identified this approach as a risk-hazard approach. The biophysical approach, although very informative, also has limitations that assessment of biophysical factors is not a sufficient condition for understanding the complex dynamics of vulnerability. This approach also neglects both structural factors and human agency in producing vulnerability and in coping or adapting to it. The approach overemphasizes extreme events while neglecting root causes and everyday social processes that influence differential vulnerability (Liverman 1990; Hewitt 1995; Pulwarty and Riebsame 1997). The third approach is the integrated vulnerability analysis, which combines both the socio-economic and biophysical factors. This approach includes all the internal state of vulnerability and external situation. This analytical approach was applied by Madu *et al.* (2012) in agro-ecological based household vulnerability analysis in Ethiopia and Deressa *et al.* (2008) in regional based vulnerability analysis.

This present study replicates an integrated vulnerability approach to develop vulnerability indices for each and every household as proposed by Madu (2012) and adopted by Tesso *et al.* (2012) in Ethiopia. In this research, it is assumed that households with higher adaptive capacity are less sensitive to impacts of climate induced stresses, thus keeping the level of exposure constant. The integrated assessment approach combines both socio-economic and biophysical approaches to determine vulnerability. The vulnerability index development is given as developed by the Intergovernmental Panel on Climate Change IPCC (2012) that vulnerability is seen as the net effect of adaptive capacity (socio-economic) and sensitivity/exposure (biophysical):

$$\text{Vulnerability} = \text{Adaptive capacity} - \text{sensitivity} + \text{exposure} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

When adaptive capacity of the household exceeds that of its sensitivity and exposure, the household becomes less vulnerable to climate change impacts and the reverse is also true. As explained in the foregoing, each set (adaptive capacity, sensitivity and exposure) is composed of different variables. The model specification further looks like:

$$V_i = A_1 X_{1J} + A_2 X_{2J} + \cdots + A_{2n} X_{nJ} - A_{n+1} Y_{1J} + A_{n+2} Y_{2J} + \cdots + A_{n+n} X_{nJ} \quad \dots\dots\dots\dots .2$$

Where V_i is vulnerability index, while X_s are elements of adaptive capacity, and Y_S are elements of exposure and sensitivity. The values of X and Y is obtained by normalization using their mean and standard errors. For instance; $X_{IJ} = \frac{X_{IJ} - X_{1*}}{S^{1*}}$, Where X_{1j^*} is the mean of X_{1j} across the different households, S_1* is its standard deviation. X_1 is the principal component result of factors. In this regard, the first principal component of a set of variables is the linear index of all the variables that captures the largest amount of information common to all the variables. The whole matrix of variables of adaptive capacity X_{ij} and variables of exposure and sensitivity Y_{ij} appears as follows:

$$\frac{X_{ij}}{Y_{ij}} = \begin{matrix} X_{11} + X_{12} + \cdots + X_{2n} & - & Y_{11} + Y_{12} + \cdots + Y_{2n} \\ & \cdot & \\ X_{m1} + X_{m2} + \cdots + X_{mn} & - & Y_{m1} + Y_{m2} + \cdots + Y_{mn} \end{matrix} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots .3$$

The i and j in the foregoing notation implies the number of rows (in this case is the 302 individual households) and the number of columns (27 variables of adaptive capacity, exposure and sensitivity). In Equation 4, the A_s are the first component score of each variable computed using Principal Component Analysis (PCA) in STATA. Finally, the vulnerability index of each household is obtained using Equation 4 as follows:

$$V_i = \begin{matrix} A_1 \\ A_{12} \\ \cdot \\ A_{n+n} \end{matrix} \times \begin{matrix} X_{11} + \cdots + X_{2n} & - & Y_{11} + \cdots + Y_{2n} \\ & \cdot & \\ X_{m1} + \cdots + X_{mn} & - & Y_{m1} + \cdots + Y_{mn} \end{matrix} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots .4$$

In calculating the direction of relationship in vulnerability indicators (that is, their sign), a negative value was assigned to both exposure and sensitivity. The justification is that households which are highly exposed to climate shocks are more sensitive to damage, assuming constant adaptive capacity. The implication is that a higher net value indicates lesser vulnerability and vice versa. However, in creating the indices, the scale of analysis is important. As quoted by Tesso *et al.* (2012) from Deressa *et al.* (2008), vulnerability analysis ranges from local or household level to the global level (Brooks *et al.* 2005). The choice of scale is dictated by the objectives, methodologies, and data availability. In this study, the households were classified into three categories based on the value of their vulnerability index, which puts households into highly vulnerable, vulnerable and less vulnerable. However, the index computed is not based on the thresholds or does it present an absolute value. It is a relative measure, representing the households' own perception of how they have been coping to the past compared to other households.

7.2.3 Factors influencing household vulnerability

Notenbaert *et al.* (2013) noted that many factors contribute to vulnerability, and these factors undermine capacity for self-protection, block or diminish access to social protection, delay recovery or expose some households to greater or more frequent hazards than other households. The analysis was performed using ordinal logistic regression analysis. The ordinal logit model is used when the outcome variable is categorized on an ordinal scale, as in this case where vulnerability is ordered as: (1) highly vulnerable, which implies households for whom the difference between adaptive capacity and sensitivity/ exposure is significantly negative; (2) moderately vulnerable, which means that households for whom the difference between adaptive capacity and sensitivity/exposure is nearly zero; and (3) less vulnerable which means that the difference between adaptive capacity and exposure/sensitivity is significantly positive. In this study, sensitivity of households to climate induced stresses is represented by its associated impacts, i.e., shortage of food, loss of water and pasture resources, and conflicts faced by those households. In the case of exposure, since all household are assumed to be located in the same environment, exposure is almost uniform across the respondent residing in the study area.

This model is particularly useful in that it can show movement between vulnerability groups, explaining who moves in and out of vulnerability. Following Greene (1997), the reduced form of the ordinal logit model is given as:

$$Y_j^* = X_j^I \beta + U_{Ij} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots 5$$

where Y is the level of vulnerability and involves ordered outcome, that is, $Y = 1$ was given to households that have high level of vulnerability as observed by the negative value of adaptive capacity minus sensitivity/ exposure; $Y = 2$ was given to households having their adaptive capacity nearly equal to their sensitivity/ exposure; and $Y = 3$ was given to households having their adaptive capacity exceeding their sensitivity and exposure. Y^* is the given state of vulnerability. The X_{ij} are the explanatory variables determining vulnerability level. The independent variables included in the model were sex and age of the household head, experience in the study area, household size and education level of the household head, dependency, marital status, social linkages and visits by extension officers, access to early warning information, non-farm income, herd size, herd structure, access to markets, property regimes, access to remittances, employment, coping strategies, herd diversity, credit access, herd mobility, climate change, experience in increased temperature, drought, floods, wind and hazards encountered in 5 year, etc. β_s are parameters estimated and U_{ij} is the disturbance term. Y^* is unobserved, but what was observed in this study is:

- $Y = 1$ if $Y^* \leq \mu 2$
- $Y = 2$ if $\mu 2 < Y^* \leq \mu 3$
- $Y = 3$ if $\mu 3 < Y^*$

Given the cumulative normal function $\Phi(\beta' x)$, the probabilities can be shown thus:

- Prob [y= 1 or highly vulnerable] $= \Phi(-\beta' x)$,
- Prob [y= 2 or neutral level of vulnerability] $= \Phi(\mu 2 - \beta' x) - \Phi(\mu 3 - \beta' x)$
- Prob [y= 3 or less vulnerable] $= 1 - \Phi(\mu 3 - \beta' x)$

7.3 Results

7.3.1 Hazards reported by households

The results show that 49% of households experienced drought over the past three decades, with 27.1% of the respondents reporting livestock disease outbreak, 19% mentioning cross-border inter-community conflicts and 4% citing riverine flash floods as the main hazard (Table 7.2). However, it was difficult for the respondents to differentiate between threats and hazards, which required clarification of the differences. Drought events were reported to be frequent hazards in the area and had devastating impacts on household livelihoods, pasture and water, which escalates the area's chronic conflicts, insecurity and food insecurity.

Inter-community and ethnic conflict related to scarce grazing land and water resources was reported to have increased inter-tribal animosity, often resulting in armed violent conflicts, which are predatory in nature and much more destructive. Households stated that violent conflicts regularly lead to heavy losses of lives and livelihoods, undermining human and livestock population mobility, as well as development efforts. Study findings show that outbreaks of *peste des petit ruminants* (PPR) locally referred to as *lomoo* is considered as the major hazard, having the highest impact on small ruminants compared to other endemic livestock diseases in the area. On further probing with community animal health workers and veterinary officers, based on the symptoms described by the pastoralist respondents, other diseases were identified as *etome* (mange), *emadang'* (worms infestation), *lukoi* (contagious caprine pleuropneumonia), *lomeri* (lump skin disease), *lokichum* (heart water), *etune* (sheep/goat pox), *lotorebwo* or *lokipi* (trypanosomiasis), *logooroi* (hemorrhagic septicaemia) and *loukoi* (contagious bovine pleuropneumonia).

Table 7.2 Hazards identified by respondents

Hazard*	Description of hazards	Number of respondents	Percentage of respondents
Floods	Flash floods along ephemeral rivers	13	4.3
Droughts	Widespread frequent droughts	148	49.0
Disease outbreak	Livestock diseases outbreak are common	82	27.1
Others i.e. Conflicts, fire	Inter-community conflicts along the borders over resources	59	19.5

*United Nations (2004) defines a 'hazard' broadly as ''a potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation''.

7.3.2 Socio-economic and bio-physical vulnerability

The social and economic variables contributing to vulnerability are summarized in Table 7.3. Findings show that more than 80% of the respondents had no basic primary education, while the majorities are not able to read and write. This in turn reduces a household's ability to understand climatic information, access market and early warning information. Data on household size showed that 64% of those interviewed had more than five persons, with 43% respondents reported more than five dependents. Whereas the sex of the household head is likely to be critical for climate adaptation, the study revealed that more than 50% of households are headed by females. In addition, 54% of the respondents indicated that they do not have access to livestock extension services. The results imply that the vulnerability level of households to the frequently occurring climate-induced stresses is largely determined by gender and education level of the household head in the study area.

More than 35.5% of the households had no diversified income sources and heavily depend on livestock as their source of income. Results show that only a few of the households were practicing dry land crop farming alongside livestock keeping. For the livestock owned, 18% of respondents had less than two tropical livestock units (TLUs[1]), and 72% of households had no milking herd during the interview period. Further, the result revealed that about 68% of households practice seasonal herd mobility and flexible resource use in the study area. The results show that 88% of households had none of its member formally employed, and 92% of respondents use more than two coping strategies to survive in this harsh climatic condition, despite the low access to credit, access to remittances and long distances to markets. Other economic concern mentioned was the high formal unemployment opportunities, especially for the youths in Turkana.

Table 7.3 displays environmental, economic and biophysical factors hypothesized for climate induced vulnerability. The results show that the sensitivity and exposure to climate variability in terms of those experiencing climate variability (96.7%) and people facing more than two hazards in 5 years (72.5%) have contributed negatively to the vulnerability level of households. Approximately 48% of the respondents noticed an increase in temperature. However, most of the environmental variables increase household's level of vulnerability to climate induced stresses as indicated by the positive sign.

[1] A TLU is the 250-kg live weight of any domestic herbivore (sheep or goat = 0.1 TLU; donkey = 0.4 TLU; cattle = 0.7 TLU; camel = 1.0 TLU).

Table 7.3 Social, economic and environmental indicators and their effect on vulnerability level

Hypothesized variables	Percentage	Influence on vulnerability[a]
Social vulnerability variables		
Sex of HH head: female-headed	50.7	+
Age of HH head: 50+ years	26.6	-
Experiences in the area: less than 5 years	7.9	+
HH size: more than 5 persons	64.6	-
Educational level: no primary education	80.1	+
Dependents: more than 5 person	43.8	-
Marital status: Single (including divorced and widowed)	29.5	+
Linkages: having no social linkages	25.8	-
Visit by extension officers: no access to extension services	54.3	+
Access to early warning information: no access to the information	74.8	+
Economic vulnerability variable		
Non-farm income: have no non-farm income	35.5	-
Herd size: own less than 2 TLU	18.3	+
Herd structure: no milking herd	72.8	+
Distance to market: more than 10km away	39.4	-
Property regime: own private land	8.6	-
Access to remittances: no cash transfers	58	+
HH employed: no member of HH employed	88.1	+
HH coping strategies: more than 2 coping strategies	92.1	+
Livestock diversity: less than 2 livestock species	45.4	-
Credit Access: having no access to credit at all	77.8	+
Mobility: able to move livestock freely	67.9	-
Environmental vulnerability variable		
Climate change: experiencing change	96.7	+
Temperature: experiencing increase	47.9	+
Drought: noticed increasing events	3.4	+
Flood: noticed change	4.1	+
Wind: noticed unusual change	11.6	+
HH facing more than 2 hazards in 5 years	72.5	-

[a]Positive sign indicates that the variable increases vulnerability, while negative sign means it reduces vulnerability. TLU, tropical livestock unit (1 TLU = 250 kg).

7.3.3 Measuring household level vulnerability

Table 7.4 highlights the result of principal component analysis and its association with the social, economic and environmental variables. The factor scores (weights) of the first principle component analysis was positively associated with the majority of the indicators identified under adaptive capacity, exposure and sensitivity. Holding exposure and sensitivity constant, a negative index shows the household to have relatively lower adaptive capacity when compared to a household with a positive index value and vice versa.

To compute vulnerability index as in Equation 2, indicators of adaptive capacity, which are positively associated with the first principal component analysis, and indicators of sensitivity and exposure, which are negatively associated with the principal component analysis were used in this study. The variables considered in Equation 2 include sex of the household head, education level, marital status, access to extension services and early warning information, livestock ownership, herd structure, access to cash remittances, household employment status, coping strategies and access to credit. However, for the exposure and sensitivity, all the variables were considered in the analysis. This is because adaptive capacity is considered as positively contributing to the reduction of vulnerability, while exposure and sensitivity are negatively contributing to vulnerability reduction. The larger the factor score the more important is the variable and contributes more to the household's vulnerability.

The households were classified into three categories using the vulnerability index: less vulnerable are households that are in a vulnerable situation but can still cope; moderately vulnerable households are those that need urgent but temporary assistance in case of shock and stresses; and the highly vulnerable are those households that are almost at a point of no return. The result shows that the majority of households fall within the moderately vulnerable category, with 44% households having an index from −1.00 to 1.00. The less vulnerable households had an index of 1.1 to 3.0 and constitute 29%, while the highly vulnerable households had an index of −0.9 to −3.0 but are 27% of the total households sampled (Table 7.5 and Figure 7.2). Although there seems to be normal vulnerability index distribution in Figure 7.2, a keen look at the values showed a slight shift to the left. Statistically, the households' distribution is skewed toward the highly vulnerable in the illustration. In general, the results reveal high and moderate vulnerability levels of the pastoralist households in Turkana.

Table 7.4 Factor score for the first principal component analysis

Factors	Factor Score
Social vulnerability variables	
Sex of HH head: female headed	0.22917
Age of HH head: 50+ years	-0.25804
Experiences in the area: less than 5 yrs.	-0.02906
HH size: more than 5 persons	-0.29837
Educational level: no primary education	0.039479
Dependents: more than 5 persons	-0.31599
Marital status: single (including divorced and widowed)	0.07224
Linkages: having no social linkages	-0.04414
Visit by extension officers: no access to extension services	0.189862
Access to early warning information: having no access	0.19573
Economic variables	
Non-farm income: HH with no non-farm income	-0.34130
Herd size in TLU: own less than 2 TLUs	0.293813
Herd structure: no milking herd	0.100562
Distance to markets: more than 10km away	-0.15870
Property regime: own private land	-0.06728
Access to remittances: no cash transfers	0.047677
HH employed: no member of HH employed	0.095173
HH coping strategies: more than 2 coping strategies	0.101335
Livestock diversity: less than 2 livestock species	-0.42800
Credit Access: having no access to credit at all	0.178153
Mobility: able to move livestock freely	-0.14718
Environmental variables	
Climate change: experiencing change	-0.02276
Temperature: experiencing increasing	0.081161
Drought: noticed increasing events	0.164723
Flood: notice change	0.039066
Wind: noticed unusual change	0.259975
HH facing more than 2 hazard in 5 years	-0.06667

Abbreviations: Households (HH), Tropical livestock unit (TLU).

Table 7.5 Classification of community by the range of their vulnerability index

Vulnerability category	Household situation	Vulnerability index	Percentage of Households
Highly vulnerable	Emergency level HHs	- 0.9 to - 3.5	27
Moderately Vulnerable	Needs urgent but temporary external assistance to recover	- 1.0 to +1.0	44
Less vulnerable	In a vulnerable situation but still able to cope	+1.1 to +3.0	29
Total			**100**

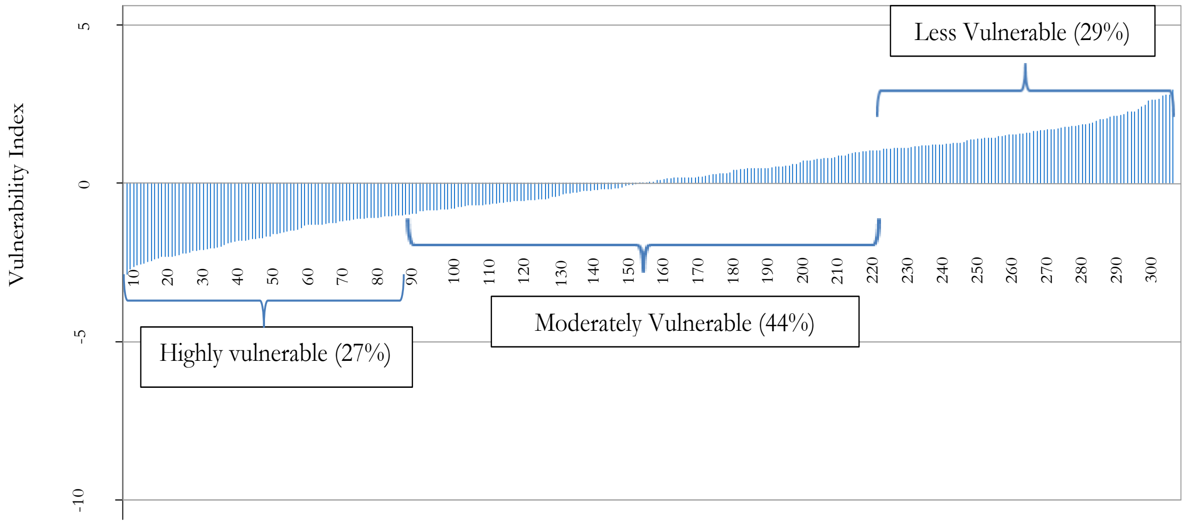


Figure 7.2 Vulnerability index by households in Kakuma, Oropoi and Lokichoggio divisions in Turkana

7.3.4 Determinants of vulnerability

The majority of highly vulnerable households were headed by females or someone with no primary level of education (Table 7.6). The highly vulnerable households also had more than five dependents, no access to early warning information, no milking herd and own less than two livestock species, and perceived changes in climate. By contrast, a household is likely to be less vulnerable when they are headed by a male, the household head is literate, not divorced or widowed, when they have access to extension services and early warning information, and own large and mixed-species herds. Similarly, households with access to cash remittances, with a member of the household in formal employment, and those with diverse coping strategies and access to credit facilities are reported to be less vulnerable to climate extremes. The results suggest that because of scarce resources during extreme climate events, households with high number of dependents and without any other livelihood diversification activities are likely to be more vulnerable than households with complementary sources of income and less dependents.

As shown in Table 7.6, the majority of households in the moderately vulnerable category are the ones with less than 5 years' experience, either divorced or widowed household heads, household heads with no social linkages, household heads with no access to extension services, households who own less than two TLUs, own private lands, households which do not received any cash remittances, household heads with more than two coping strategies, households who practice mobility and are able to move freely with their livestock herd, and perceive climatic changes in the area.

The results of the ordered logistic regression model for all the single predictors' variables influencing a household's vulnerability are summarized in Table 7.7. A number of variables were statistically significant at 1% and 5% levels of significance and were important in influencing households' vulnerability to climate-induced stresses. The variables that showed significant influence on vulnerability include gender of the household head, age of the household head, size of the household, number of dependents, marital status, access to extension services and early warning information, complementary sources of income, herd diversity and structure, coping strategies and access to credit.

The higher odds ratios computed for age of the household head, household size, dependents, complementary income sources, herd diversity and mobility imply that these factors have more effects on the households' vulnerability level. But it should be noted that majority of the sampled population derived their means of subsistence from nomadic pastoral production system which are weather sensitive and therefore absence of non-agricultural income sources (salary or wages labour) which are not weather sensitive would be a significant determinant on vulnerability level as reflected in the odds ratio figures. Herd diversity and mobility allow households to spread risk and pursue various coping strategies. Herd mobility was observed to be a significant (at 5%) determinant of households' vulnerability to climate variability and change.

Table 7.6 Statistical description of model variables by vulnerability category

Vulnerability variables	Vulnerability Category		
	Less vulnerable	Vulnerable	Highly vulnerable
Sex of HH head: female	67(44%)	62(20%)	24(45%)
Age of HH head: 50+ years	6(41%)	33(34%)	35(25%)
Experiences in the area: less than 5 yrs.	10(16%)	10(44%)	4(4%)
HH size: more than 5 persons	27(8%)	92(22%)	76(42%)
Educational level: no primary education	72(45%)	107(5%)	63(55%)
Dependents: more than 5 person	10(47%)	58(41%)	59(33%)
Marital status: single (including divorced and widowed)	31(42%)	41(55%)	17(46%)
Linkages: having no social linkages	18(42%)	34(52%)	26(21%)
Visit by extension officers: no access to extension services	67(17%)	65(39%)	32(20%)
Access to early warning information: having no access	77(14%)	100(9%)	49(45%)
Non-farm income: HH with no non-farm income	5(47%)	43(33%)	58(34%)
Herd size in TLU: own less than 2 TLUs	23(39%)	17(44%)	4(31%)
Herd structure: No milking herd	72(30%)	97(23%)	51(42%)
Distance to market: more than 10km away	20(44%)	51(18%)	40(27%)
Property regime: own private land	4(26%)	13(46%)	9(40%)
Access to remittances: no cash transfers	58(8%)	71(36%)	46(30%)
HH employed: no member of HH employed	81(46%)	118(15%)	67(30%)
HH coping strategies: more than 2 coping strategies	82(46%)	121(50%)	66(25%)
Livestock diversity: less than 2 species	5(35%)	57(35%)	75(58%)
Credit Access: having no access to credit at all	78(46%)	108(33%)	49(17%)
Mobility: able to move livestock freely	42(19%)	93(41%)	70(32%)
Climate change: experiencing change	43(23%)	59(26%)	38(47%)
Drought: noticed increasing events	4(44%)	3(30%)	3(21%)
Flood: noticed change	3(33%)	7(44%)	2(29%)
Wind: noticed unusual change	11(41%)	16(25%)	7(45%)
HH facing more than 2 hazard in 5 years	63(40%)	99(30%)	57(26%)

HH, Households; TLU, Tropical livestock unit

From the ordered regression results, 75% of female-headed households are more likely to be vulnerable climate induced stresses and shocks compared to the average male-headed households. This might be because female-headed households normally face gender discrimination with respect to resources, rights, education, income and economic opportunities.

Household age was also an important demographic factor determining how vulnerable a household could be. For example, households headed by person above 50 years of age are more likely to be vulnerable compared with the younger persons. Consequently, elderly household heads are probably worse off in terms of preparing strategies to cushion their families against adverse climatic stresses and impacts and likely to make them more vulnerable. Similarly, the more dependents a household has the more likely for it to be vulnerable since a larger proportion of household resources are directed to dependents who cannot contribute much toward household welfare. Further results also show that widowed or divorced single-headed families are 37.4% more likely to be vulnerable than families where both spouses are present. According to the study results, it was observed that livestock diversity had higher odds ratio of 29.592, which suggest that households with more than two livestock species are 28 times more likely to shift from highly vulnerability category to moderately vulnerability level.

Table 7.7 Factors influencing household's vulnerability

Variables	Estimate	SE	OR	z	P value
Sex: female headed	-1.3828	0.2303	0.2509	-6.0049	<0.0001*
Age: 50+ years	1.5714	0.2704	4.8134	5.8106	<0.0001*
Experiences in the area: less than 5 yrs.	-0.6187	0.399	0.5386	-1.5506	0.1220
HH size: more than 5 persons	2.2155	0.2651	9.1663	8.3585	<0.0001*
Educational level: illiterate and less than class 8	-0.1754	0.2684	0.8391	-0.6534	0.5140
Dependency: High dependency of 5 person and more	2.1434	0.2639	8.5281	8.1212	<0.0001*
Marital status: single (including divorced and widowed)	-0.4689	0.2349	0.6257	-1.9965	0.0468*
Linkages: Having no social linkages	0.4232	0.2456	1.5268	1.7233	0.0859**
Visit by extension officers: no access to extension	-1.0717	0.2237	0.3424	-4.7909	<0.0001*
Access to early warning information: Having no access	-1.017	0.2535	0.3617	-4.0119	<0.0001*
Non-farm income: Have no non-farm income	2.3332	0.2715	10.3108	8.5946	<0.0001*
Herd size in TLU: Own less than 2 TLU	-1.8785	0.3414	0.1528	-5.502	<0.0001*
Herd composition: No milking herd	-0.668	0.2434	0.5128	-2.7442	0.0064*
Access to market: More than 10km away	0.7694	0.2301	2.1586	3.3442	<0.0001*
Property regime: own private land	0.5666	0.375	1.7623	1.5111	0.1318
Access to remittances: No cash transfers	-0.2696	0.2161	0.7637	-1.2477	0.2131
HH employed: No HH employed	-0.6226	0.3337	0.5365	-1.866	0.0630**
HH coping strategies: less than 2 coping strategies	-1.0896	0.4268	0.3363	-2.5529	0.0112*
Livestock diversity: less than 2 livestock species	3.3875	0.3506	29.592	9.663	<0.0001*
Credit Access: Having no access to credit at all	-1.1825	0.2703	0.3065	-4.3753	<0.0001*
Mobility: Able to move livestock freely	1.2984	0.2424	3.6635	5.3571	<0.0001*
Temperature: Experience increasing temp.	-0.0412	0.2175	0.9597	-0.1892	0.8500
Drought: Noticed increasing events	-0.2123	0.6269	0.8087	-0.3387	0.7350
Flood: Noticed change	-0.1252	0.5225	0.8823	-0.2396	0.8108
Wind: Noticed unusual change	-0.2462	0.3355	0.7818	-0.7338	0.4636
People facing more than 2 hazard in 5 years	-0.0369	0.2409	0.9638	-0.1532	0.8784

Source: Results of ordinal logistic regression model: single predictors; SE standard error, OR odd ratio, z score of two sample tests (basically a t test) though using the standard normal to calculate the *p* value and expressing the statistically significance levels at * 5, and ** 10%.

Although 27 variables were hypothesized to be correlated with vulnerability, ordinal regression model result confirmed that only 17 factors were significant (at $p < 0.1$ and $p < 0.05$) in influencing households' vulnerability. Although not computed in this present study, it should be noted that different determinants have differential effects on a household's vulnerability levels.

7.4 Discussion

Drought was considered by the respondents as one of the most frequent hazards in Turkana, in addition to other hazards such as conflicts, disease outbreaks and flooding. The pastoralist respondents maintained that frequent, prolonged drought events have increased in severity over the past decade or so. This perception corroborate Nicholson's (2014) assertion about drought events in northern Kenya, with rainfall being at least 50% to 75% below normal in almost half of the drought-stricken region and is likely to be linked to changing climatic conditions within the greater Horn of Africa. However, there is a great deal of uncertainty and tension about when, where and how much climate changes will happen. Even less is known about the actual impacts of these perceived changes (Kabubo-Mariara 2009; Notenbaert *et al.* 2013; Intergovernmental Panel on Climate Change IPCC 2014) to the dry land communities. It is argued that due to the frequency of shocks in the study area, some of the coping capacity used by vulnerable households could well have equal or larger ranges to that of exposure and sensitivity to hazards. As discussed earlier on vulnerability, the interaction of environmental (biophysical) forces determines exposures and sensitivities, and various social, cultural, political and economic forces shape adaptive capacity (Yohe and Tol 2002; Turner *et al.* 2003; Skjeflo 2013).

In the study area just like the rest of northern Kenya, pastoralist households largely bear the brunt of negative impacts of extreme climate events like drought, which include increased poverty, water scarcity, resource-based conflicts, disease outbreaks and food insecurity. The majority of people in Turkana live below the absolute poverty line (an estimated 87.5% of the population) with more than 50% heavily relying on food aid and safety net programmes from year to year. The people who are already poor in this remote part of the country are struggling to cope with the added burden of increasingly unpredictable weather, which is triggered by climate variability and change. Evidence shows that Turkana is constrained by the harsh climatic conditions and remoteness, coupled with poor infrastructure and low access to essential services

(Republic of Kenya 2012). Previous studies (Thornton *et al.* 2006a; Kabubo-Mariara 2009) in the region confirmed that it is becoming increasingly difficult for households to bounce back from ever-changing, inconsistent weather affecting their livelihoods, and many have been forced to pursue other livelihoods and coping mechanisms that only increase the cycle of vulnerability.

This study has shown that female-headed households, households with experience of less than 5 years in the area, household heads with no primary level of education and households headed by divorced and widowed persons, with no access to extension services and early warning information, in particular, are disproportionately likely to be affected by climate stresses and variability. In times of climate stresses and shocks like drought, these categories of households tend to have fewer options to find other ways of making a living, because their very low levels of literacy reduce their opportunities in coping mechanisms such as wage employment. Similarly, female or divorced and widowed household heads are likely not to be empowered enough in pastoral communities to make household decisions (Nabikolo *et al.* 2012) and are frequently without access to credit services and adequate capital assets or not able to own large herds to manage households' daily requirements. Similar observations have been made by Kakota *et al.* (2011) in Malawi and Tesso *et al.* (2012) in Ethiopia that widowed or divorced household heads are more vulnerable because they rely on income earned by either the father or mother as the bread winners. These findings make a strong case for continuous targeting of pastoralist women in resilience-building interventions in the rangelands.

The results are consistent with previous findings (Deressa *et al.* 2008) in similar ecosystems. However, for the biophysical variables, the greater the level of household reliance on natural resources, such as pastoralism or dry land crop farming, the greater will be their vulnerability to climate variability and change. This is partly because the use of such natural resources is dependent on rainfall, which is projected to change. This study observed that almost all the postulated biophysical/ environmental variables contribute positively to household vulnerability. It is likely that the level of dependence on natural resources especially pastures and water will vary from household to household. For example, while the majority of households (78.9%) depend on livestock herding as their main source of livelihood, for others, livestock is just an equal or lesser contributor besides other economic activities.

The level of vulnerability is closely associated with the degree of poverty in Turkana. This county has higher degrees of vulnerability in terms of households' adaptive capacity or social and economic characteristics that are linked to their exposure and sensitivity to biophysical variables (Lo´pez-Carr *et al.* 2014). The findings of this study suggest that in case of an external stress or shock, the majority of the households would need some assistance for them to recover. These results reflect the findings of studies by Kenya National Bureau of Statistics (KNBS) (2013) which showed that Turkana is the poorest county in Kenya, with 87.5% of the population living in absolute poverty. Other studies have indicated that Turkana region has a number of households with high of dependents, low engagement in off-farm activities and low levels of education (Blench 2000; McPeak and Barrett 2001; Watson and van Binsbergen 2008).

The determinants of households' vulnerability were found to be significantly influenced by the sex of the household head, age of the household head, size of the household, number of dependents, marital status, social linkages, access to extension services and early warning information. In addition, non-farm income, herd size and diversity, herd structure and herd mobility, access to markets, households' employment status, coping strategies and access to credit were also observed to be the key determinants of the households' vulnerability to climate-induced stresses. This concurs with studies by Eriksen *et al.* (2005) and Notenbaert *et al.* (2013) which similarly observed some of these factors to be the key determinant of households' vulnerability to climate variability and change in rural communities. The results are also consistent with previous findings by Kakota *et al.* (2011) and Gebrehiwot and van der Veen (2013). From these findings, it seems there is still more to be done to understand vulnerability and its underlying processes. In this paper, the causal relationships between the statistically significant variables and outcomes in terms of vulnerability levels are explained using existing literature. Some of these explanations are, however, rather speculative and not confirmed for the local situation. More in-depth qualitative fieldwork, such as including open-ended questions, conducting focus-group discussions or in-depth interviews with selected households based on these factors, could strengthen our confidence in some of these explanations. The combination of quantitative surveys with qualitative autopsy is likely to provide a much more in-depth analysis of determinants of vulnerability.

7.5 Conclusions

Understanding vulnerability to environmental change and extreme climate events is necessary for policy makers to develop mitigation and adaptation programmes for long-term resilience. Vulnerability analyses contribute to the knowledge on climate-sensitive socio-economic or ecological systems, enabling policy to be targeted on the most vulnerable places, sectors or people and adaptation options to be defined. The results of this study from Turkana portray social and biophysical vulnerability indices which are useful to local development programming for long-term resilience. However, as a prerequisite for building households' resilience to climatic extremes, in-depth understanding is necessary of the adaptive capacity, exposure and sensitivity.

This study focused on the micro-level to assess the variability of vulnerability across different households. Categorization of vulnerability levels was used to help identify households that are not vulnerable currently but have a high probability of becoming vulnerable in the future. In the future, studies assessing household-level vulnerability to climate-induced stresses should explore the use of panel data as well as cross-sectional data to portray longitudinal and cross-sectional characteristics of households. Similarly, future resilience interventions should target individual households within a community because major decisions about adaptation to climate induced stresses and livelihood processes are taken at the micro-level.

We conclude that because of various social, economic and biophysical determinants observed to influence households' vulnerability to climate-induced stresses, policies with emphasis on women's empowerment, promoting education, supporting extension services and enhancing diversifications of income sources and access to credit, supporting herd mobility and diversity, creating employments, and increasing access to markets and early warning information are likely to improve resilience of pastoral households. Although the results of this study are specific to Turkana County in Kenya, the approach and findings could be applicable to other arid and semi-arid areas in the region.

CHAPTER EIGHT

VEGETATION RESPONSE TO PRECIPITATION ANOMALIES IN NON-EQUILIBRIUM RANGELANDS OF TURKANA, KENYA

Abstract

This study explores possible linkages between rainfall and Normalized Difference Vegetation Index (NDVI) in non-equilibrium rangelands of Turkana, Kenya. A sequence of 14-years (1998-2011) monthly NDVI datasets from the Advanced Very High Resolution Radiometer (AVHRR), and precipitation datasets (1965-2011) from Kakuma, Oropoi and Kakuma were examined. Findings revealed that below normal rainfall occasioned by climate variability and change is persistent with effects on vegetation greenness and consequently pastures production in Turkana. Overall, the study area show enhanced green vegetation coverage. However, results suggest that October- December (OND) precipitation is more reliable and showed strong positive correlation with vegetation anomalies than the March – May (MAM) precipitation. Further results suggests that areas with low mean annual rainfall of ≤ 200 mm such as Oropoi and Kakuma depict a stronger and significant relationship between NDVI and rainfall compared to Lokichoggio with annual rainfall of ≥300mm. However, the recovery of vegetation greenness beyond what would be expected from the rainfall conditions alone could partly be associated with invasion of the rangeland by *Prosopis juliflora,* and increased inaccessibility of the vast grazing areas due to insecurity. Overall, results revealed that observed vegetation trends are not exclusively explained by rainfall variability but also by other biophysical characteristics and land use changes. In addition, observed linkages between NDVI anomaly and seasonal rainfall in each location suggest the association is better discussed for each individual location than for the entire study area. This study has demonstrated that monitoring of vegetation dynamics from satellite measurements could lead to a better understanding of temporal-time variability in more arid ecosystems. It was concluded that the relationship between rainfall and NDVI is not a simple linear one, and must be based on detailed analysis of vegetation type for ground truthing.

Key words: Climate variability, AVHRR-NDVI, rainfall anomaly, arid and semi-arid ecosystems, Kenya

8.1 Introduction

The arid and semi-arid rangelands of Kenya are estimated to cover 89% of total land mass, and are subject to regular seasonal dryness and large inter-annual variability in precipitation (ASAL policy 2012). Since early 1980s these rangelands have experienced a systematic large variation in precipitation and widespread extreme weather events (Mutai *et al.* 2012; Nicholson 2014). The large variations and trends in precipitation have resultant effects on vegetation dynamics, and ecosystem structure and functions, especially in the arid and semi-arid ecosystems where moisture availability is one of the most important constraints on vegetation growth and development (Anyamba and Tucker 2005). Studies show that the mechanisms that govern atmosphere-plant-soil processes are strongly influenced by water availability and any subtle shift in rainfall influence the ability of plants vegetation to respond to such changes (Scholes and Walker 1993; Herrmann, *et al.* 2005; Mortimore 2009; Huber *et al.* 2011; Gaughan *et al.* 2012; Gessner et al 2013). Similarly, studies by Fuller and Prince (1996), and Eklundh (1998) show that the productivity of vegetation depends on the adequate amount and right timing of plant moisture available. Many rangeland areas show non-equilibrium behaviors in which short-term rainfall variability imposes dramatic changes in vegetation cover that mask downward trend in condition except in the most extreme cases (Pickup *et al.* 1998). It implies therefore, that the relationships between vegetation production and precipitation are not only determined by total rainfall but also by precipitation timing and variability as well as the ecological zone. However, there is paucity of information on the responses of vegetation to precipitation anomalies, especially for non-equilibrium rangelands of Kenya. An improved understanding of vegetation sensitivity to precipitation anomalies and corresponding temporal reaction patterns at a more local scale is therefore critical for these arid and semi-arid ecosystems.

Under different scenarios of projected climate variability and change, many ecosystems in eastern Africa may become even drier and precipitation timing and amount may shift (Thornton *et al.* 2009a; IPCC 2014). Although projections of precipitation amount are not fully consistent in the region, other climate analyses suggest that there will be slight decrease of average annual precipitation to the middle of the twenty-first century (Hulme *et al.* 2001). Other studies by Thornton *et al.* (2010) indicate that parts of eastern Africa will become drier, with considerable reduction in the length of the growing season. In Kenya for example, the global climate models predict that, by the year 2100, climate change will increase temperatures by about 4-7°C, shift in rainy seasons, more erratic rainfall patterns and cause inter-annual rainfall variability by up to 20% (WWF 2006; Kabubo-Mariara 2008). Such projected changes will likely create fundamental changes to ecosystem structures and functions. Over the past decade, many scientists have been devoting considerable amount of time and resources to assess arid ecosystem responses to natural and anthropogenic disturbance all over the world with contradictory results. Most of these studies rely on time-series of remotely sensed vegetation indices such as normalized difference vegetation index (NDVI) which have been widely used as surrogates of vegetation canopy greenness and primary productivity. For large areas and long time frames analyses, several authors have demonstrated the usefulness of National Oceanic and Atmospheric Administration (NOAA)-AVHRR (Advanced Very High Resolution Radiometer) and Aqua-MODIS (Moderate Resolution Imaging Spectro-radiometer) satellite sensors to monitor NDVI to provide spatially and temporally consistent proxy information on vegetation dynamics in the region (Tucker *et al.* 1986; Di et al 1994; Richard and Poccard, 1998; Martiny *et al.* 2005). The NDVI index is based on red and near infrared reflectance, recorded by remote sensing, and is calculated from AVHRR measurements as in equation 1.

$$\mathrm{NDVI} = \frac{\mathrm{pn} - \mathrm{pr}}{\mathrm{pn} + \mathrm{pr}}, \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (1)$$

where pn is near-infrared reflectance and pr is red reflectance as measured by the satellite instrument (Tucker *et al.* 2005). The normalized difference of these reflectance is an index of ecosystem production and provides a robust means to estimate vegetation health and dynamics by quantifying the ‘greenness’ of vegetation in a landscape (Wang *et al.* 2003). NDVI as a measure of vegetation greenness can be problematic in tropical forests as its calculated value can saturate at high foliage biomass, but this is less of a concern in the semi-arid regions as observed by Nicholson and Farrar (1994), and Richard and Poccard (1998). However, it is not only leaf absorption and scatter that are measured by NDVI but also other factors such as bare soil, leaf litter type, vegetation structure and composition (Farrar *et al.* 1994). These factors make NDVI a composite measurement of leaf chlorophyll, canopy cover, vegetation structure and background reflectance, therefore encompassing more than just leaf chlorophyll in its measurement of vegetation greenness (Nicholson and Farrar 1994; Plummer 2000). NDVI is also affected by sources of noise, ranging from sensor attributes to atmospheric conditions, which influence the remote observations of greenness (Azzali and Menenti 2000; Hijmans *et al.* 2005). Despite this, a strong correlation exists between vegetation production indexed by NDVI and average climatic distribution of precipitation in most ecosystems (Scanlon *et al.* 2002; Goward *et al.* 2003; Hellden and Tottrup 2009), making it useful for understanding the effects of wet season months on vegetation greenness leading into the dry season. The NDVI is the oldest remotely sensed vegetation index in use and remains, despite its shortcomings in terms of sensitivity to soil colour, atmospheric effects, and illumination and observation geometry.

A number of studies conducted in arid and semi-arid ecosystems show that time series of remotely sensed NDVI can be a reliable indicator of physical climate variables including rainfall, temperature, and evapotranspiration in a wide range of environmental conditions (Gray and Tapley 1985, Nicholson *et al.* 1990, Anyamba and Tucker 2001). NDVI may also be considered to represent the integration of land surface responses to climate variability at various time and space scales. In addition, NOAA-AVHRR NDVI series have also been used to study the inter-annual variability produced by El Nin˜o-Southern Oscillation (ENSO) events (Seiler and Kogan 2002, Gurgel and Ferreira 2003, Poveda and Salazar 2004). While the relationship between vegetation and precipitation in high rainfall areas has received much attention in the recent past relatively few studies have focused on such links in the arid and semi-arid ecosystems in northern Kenya (Shisanya *et al.* 2011). A better understanding of these relationships could improve general knowledge on possible rangelands ecosystem responses to climate variability and change. It would help in identifying regions which are particularly prone to precipitation anomalies and would provide important baseline information which is necessary for climate prediction and early warning to extreme climate events such as droughts. This study therefore constitutes one of the attempts aimed to study the relationships between rainfall and NDVI at different spatial and temporal scales in north-western Kenya. The aim of this study is to contribute to an improved understanding of vegetation responses to precipitation anomalies and corresponding temporal reaction patterns in non-equilibrium rangelands of Turkana, Kenya. The study addressed the following specific questions:

i) What are the observed vegetation patterns as represented by vegetation index data from January 1998 to December 2011 in the study area?

ii) How does vegetation respond to precipitation variation for the period 1998-2011 in Turkana? and

iii) Was there any relationship between NDVI trend observed and the actual vegetation sampled from across the landscape?

This study provides empirical findings of the relationship between precipitation and NDVI in Turkana to facilitate the use of NDVI data in related ecological studies. However, compared with previous studies, this research uses time series, high-resolution data in space. In this way, the study anticipates that satellite data could be applied to provide a better understanding of temporal precipitation variability in relation to ecosystems structure and function in truncated ecosystems.

8.2 Methods

8.2.1 Data collection

8.2.1.1 Rainfall

The monthly precipitation data were obtained from the Kenya Meteorological Services (KMS) archives for various locations used in the study. From the monthly rainfall data, the annual means were calculated for Kakuma (3.7167° N; 34.8667° E), Lokichoggio (4.2000° N; 34.3500° E) and Oropoi (3.4600° N; 34.1401° E) locations. The monthly rainfall of the each station was summed based on MAM, and OND to provide the seasonal total rainfall of each year. Throughout the recorded history, it has been observed that the frequency of droughts has increased through time in the study area.

8.2.1.2 Normalized difference vegetation index

The Normalized Difference Vegetation Index (NDVI) derived from the AVHRR satellite, with dataset for the period 1998-2011 and reasonably spatial pixel resolution of 8 by 8 km provides an excellent tool for the analysis of vegetation anomalies within the three spatial domains namely Lokichoggio, Kakuma and Oropoi used in this study. AVHRR 10 day’s composite of surface reflectance for both minimum and maximum NDVI were obtained from International Livestock Research Center (ILRI) database in Nairobi, Kenya for this study.

The monthly NDVI values were then averaged for each of the three administrative units covered in Turkana. Since NDVI is thought to be closely related to rainfall seasonality (Anyamba and Tucker 2005), the analyses were confined primarily to the 'long' and 'short' rainy seasons, which account for most of the rainfall received in a year. The months of March, April and May, hereafter referred to as MAM long rains growing period, while October, November through December (OND) represent the short rains growing period. The long-term NDVI climatology (1998-2011) was created by averaging data for all cloud-free pixels for MAM and OND for the same period. NDVI data are separately normalized in order to give the same weight to all the grid-points and to both NDVI and rainfall, which are put together into a single matrix. The year to year variability in the NDVI patterns was examined by calculating yearly MAM and OND anomalies as follows:

$$NDVI\sigma = \frac{NDVI\alpha}{NDVI\mu \; -1} \; 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; (2)$$

where: NDVIσ are the respective MAM and OND anomalies, NDVIα are individual seasonal MAM and OND means and NDVIμ is the long-term MAM and OND mean. The NDVI is unit-less, with values ranging from –1 to +1. Healthy green vegetation normally has the highest positive values while surfaces without vegetation, such as bare soil, water, snow, ice or clouds usually have low NDVI values that are near zero or slightly negative.

8.2.1.3 Vegetation species

A systematic sampling was undertaken for ground truthing for discussing vegetation species richness and abundance in relation to satellite NDVI data observed. Plot transect was used for vegetation sampling across the sampled locations in Turkana. Three 6-km long transects were mapped out along the road from Lokichoggio, Oropoi to Kakuma. In each of transect, six perpendicular lines sub-transects measuring 100 m each were cited at regular intervals of 1 Km along the main transect. On each sub-transect, two main plots each measuring 10 m by 10 m were marked out on both sides. A total of 28 plots were established. On each sample plot data on species richness, abundance, and cover for trees, shrubs and herbs was collected.

8.2.2 Statistical analyses

The rainfall datasets were normalized according to formula of Farmer (1986):

$$Normalized\ Rainfall = \frac{\text{seasonal rainfall total} - \text{long term mean}}{\text{Long term standard deviation}}$$

(Farmer 1986)

Descriptive statistics was used to determine the mean annual rainfall, standard deviation and coefficients of variation for the selected locations. Simple linear regression was used to find the relationship between mean annual and seasonal rainfalls on NDVI. In order to test the strength of correlation relationship between NDVI and precipitation time series data, Pearson's correlation coefficients were calculated for each location across the study area. The correlation analyses were done for all seasonal rainfall months (MAM and OND) and also for lagged NDVI (AMJ and NDJ) months. The correlations were considered significant at $P<0.05$. The NDVI data were geo-registered and inverse weighted (Kriging) used for predictions interpolated with the coordinates in order to generate seasonal maps.

Repeated measures of ANOVA (SYSTAT Inc. 1992), F-test was used to compare the effects of time from years (1998-2011) on total vegetative cover for each study location. The year was considered fixed effects for analysis of variance. Statistical tests were considered significant at $P<0.05$.

8.3 Results and Discussion

8.3.1 Annual and seasonal rainfall anomalies

The rainfall is generally low and varies slightly from 150.5 mm in Kakuma, 204.7 mm at Oropoi and 316.7 mm in Lokichoggio with a combined average of 224 mm. The coefficient of variation in the three locations revealed that rainfall in the region has high inter-annual spatial variability. The results indicate that percent coefficient of variation for annual rainfall at Oropoi (CV>152%), Kakuma (CV>134%), and at Lokichoggio (CV>117%) were extremely high (Table 8.1). According to Ellis (1995), coefficient of variation more than 33% in a rangeland is thought to exhibit non-equilibrium dynamic. In view of the direct effect of seasonal rainfall on agricultural production and pasture resources in the rangelands, high variability could tremendously affect the lives and livelihoods of the pastoral community in the area. The study revealed that approximately 57% of the years between 1998 and 2011 in Lokichoggio and Oropoi were characterized by suppressed (below) normal rainfall. However, the rainfall amount received in Oropoi and Kakuma were not significantly different. Lokichoggio rainfall amount received differed significantly (p<0.05) with the other two study locations.

Table 8.1 Location of the study stations, seasonal and annual rainfall for the period 1998-2011

Spatial	Coordinates		Seasonal Rainfall (mm)		Annual rainfall (mm)				
	Latitude	Longitude	MAM	OND	Annual mean	Std deviation	%CV	% Below mean	Database period
Lokichoggio	4.2000° N,	34.3500° E	115.0	112.6	316.7	28.0	117%	57.1	1998 -2011
Oropoi	3.4600° N	34.1401° E	90.8	58.9	204.7	25.2	152%	57.0	1998 -2011
Kakuma	3.7167° N,	34.8667° E	60.2	45.1	150.5	15.7	134%	42.9	1998 -2011

Author compilation from the meteorological rainfall data from Kenya Meteorological Services - KMS; March-April (MAM), October-December (OND), and percent coefficient of variation (%CV).

Results show that there was high seasonal (MAM and OND) rainfall variability for the period between 1998 and 2011 in the study area. A noticeable feature is that, whereas the short rains get generally less rainfall than the long rains, the November peak rainfall is almost as high as and sometimes higher than the April one. An interesting case in this respect is that of Lokichoggio, where the maximum rainfall peak obtained in April is less than that received in November. However, the MAM contribution to the total annual rainfall in the study area varies from 35 to 45% depending on the station location. It was observed also that the OND rainfall makes a considerable contribution to the annual rainfall totals as observed in Oropoi (29%), Kakuma (30%) and Lokichoggio (36%). Seasonal analysis further revealed that approximately 5 years received below normal MAM rainfall in the study locations. Similarly, the OND rainfall in 1998, 2000, 2003, 2009 and 2010 recorded below normal rainfall for Lokichoggio, Kakuma and Oropoi. Of these five years with below normal rainfall, 2000 and 2001 had the most pronounced depressed rainfall with all the three sites recording a negative normalized precipitation index during the OND rainfall. The study result revealed that that 2010/2011 was not the worst hydrological drought year as reported elsewhere. For example, the lowest normalized rainfall values recorded for all the three locations was -0.21 for MAM and -0.32 for OND rains in 2010, while the normalized OND rainfall in 2011 were all positive. Overall, Lokichoggio received the highest amount of rainfall compared to Oropoi and Kakuma which received the least between 1998 and 2011. Seasonal rainfall for MAM and OND was not significantly different (p=0.176). Moreover, the study revealed that the frequency of below normal rainfall seems to have increased in the last 14 years in Turkana. In this regards, more than 42% of the years in the last decade had recorded below long-term average in the three locations. It also emerged that the three locations had more years with above normal rainfall during OND season than preceding MAM rainfall (Table 8.2).

In 1998, Kakuma received below normal rainfall during the MAM and OND rainfall seasons despite National Centre for Environmental Prediction (NCEP's) classification of the year as El Niño. However, the 2000 and 2003 are fairly unique years in that MAM and OND seasons recorded above normal rainfall respectively for all the three locations, culminating into a decline in seasonal rainfall in 2008. In fact, 2008/9 was prolonged drought period in Turkana County as a result of failed MAM rainfall. Previous studies have strongly linked El Niño-Southern Oscillation (ENSO) events with OND rainfall in Eastern Africa; but there is scanty literature on ENSO-MAM seasonal rainfall in the region (Phillips and McIntyre 2000; Goddard *et al.* 2001; Shisanya *et al.* 2011). The results of this study is a pointer to the need to determine the influence of ENSO events at local level in the arid zone of Kenya and prepare local communities on the potential impact of these events. It was concluded that the rainfall pattern changes markedly, both in amount and seasonality, over relatively small distances and time scale.

Table 8.2 Normalized MAM and OND rainfall for Lokichoggio, Oropoi and Kakuma stations over the period 1998-2011

Station	**1998**		**2000**		**2003**		**2006**		**2009**		**2011**	
	MAM	OND	MAM	OND	MAM	OND	MAM	OND	MAM	OND	MAM	OND
Lokichoggio	0.59	**-0.15**	**-0.74**	**-0.34**	**-0.18**	**-0.26**	**-0.17**	0.95	**-0.20**	0.85	0.04	4.31
Oropoi	1.15	0.32	**-0.35**	0.24	0.32	**-0.01**	0.23	0.85	0.19	1.10	0.76	4.31
Kakuma	**-0.28**	**-0.74**	**-0.90**	**-0.87**	**-0.68**	**-0.86**	**-0.89**	**-0.57**	**-0.83**	**-0.49**	**-0.32**	**3.80**

Source: Author compilation from the rainfall datasets; Negative and positive indicate below and above rainfall events, respectively.

8.3.2 NDVI time series pattern

The time series of NDVI values for growing seasons (MAM and OND) at Lokichoggio, Oropoi and Kakuma in the north-western part of Turkana for the period 1998-2011 are shown in Figure 7.1. The effects of time/years on the NDVI anomalies for all the study locations were considered in an ANOVA. The time had a significant influence on NDVI during both the MAM (F = 5.124, p=0.0001, df = 13) and OND (F=11.03, p= 0.0001, df = 13) growing seasons. In all the three study locations, the observed vegetation greenness for the period 1998-2011 were significantly (p =0.05) influenced by time, and varies from over the years. There was a steady increase in NDVI values both for MAM and OND growing season between 1998 and 2009, however, 2010 and 2011 showed a very sharp increase on vegetation greenness in the entire study area.

Overall, NDVI values differed significantly with each other, with Oropoi having the highest average NDVI followed by Lokichoggio and Kakuma with the lowest. The variability of these patterns show the underlying patterns of vegetation formation and types which tend to vary in structure across the study area. However, despite the perceived decrease in vegetation attributes (Okoti *et al.* 2004), all the sites showed positive trends in NDVI through the satellite time series data. Implying that there has been increase in vegetation greenness in the study locations. The most pronounced trends was observed in Oropoi which show a systematic positive trend with NDVI values increasing consistently from the lowest in 2000 to a peak in 2011. These peaks and lows naturally represent the rainy and dry periods. However, all the sites show the persistence of the drought events in 2000 and 2008 with a dramatic decrease in NDVI values, and then increasing gradually to the highest levels by 2011 in all the three locations. The decrease in vegetation coverage in 2000 and 2008 is likely due to the decrease of rainfall amount in the study locations. In contrast, there are also moderate variations in the 2000 NDVI trend (La Nin˜ a year) when compared to the 1998 NDVI trend (El Nin˜ o year). This result suggests that NDVI variations cannot entirely explain explained by rainfall dynamics in the study area. The recovery of vegetation greenness beyond what would be expected from the rainfall conditions could be attributable to increased inaccessibility of the grazing area in Oropoi as a result of conflicts. In parts of Lokichoggio is as a result of insecurity, and invasion of the study sites by *P. juliflora*.

The study findings revealed that driest years had the lowest vegetation greenness while the wettest years had maximum NDVI values. For instance, during the MAM season, 2000 and 2001, 2006 and 2009 recorded the lowest NDVI values for April-June in the region. Previous studies showed widespread drought episodes in the entire Horn of Africa during 2008/9 (Ndathi *et al.* 2012), which resulted to between 40 -70% livestock mortality in northern Kenya as result of pasture and water scarcity occasioned by failed rainy seasons (Huho and Mugalavai 2010; Zwaagstra *et al.* 2010). The 2008/9 drought episode was one of the severest on record in Kenya over the past decade with widespread socio-economic impacts (Musingi 2013), that included famine and a decline in the length of the growing season. Although the rainfall amount received was not the highest in Oropoi, the magnitude of NDVI variation was the highest compared to Kakuma and Lokichoggio. This could imply that rainfall amount is not the only determinant of vegetation greenness and coverage observed in non-equilibrium ecosystems. Studies by Okoti *et al.* (2004) established that in addition to rainfall amount, factors such as soil type, deforestation, overgrazing, and land use activities determine primary biological productivity of the rangelands in Turkana. In the case of Kakuma, rainfall distribution, alongside bio-physical characteristics such as presence of high populations of both human and livestock around the settlement camp could be a major determinant of vegetation greenness anomalies.

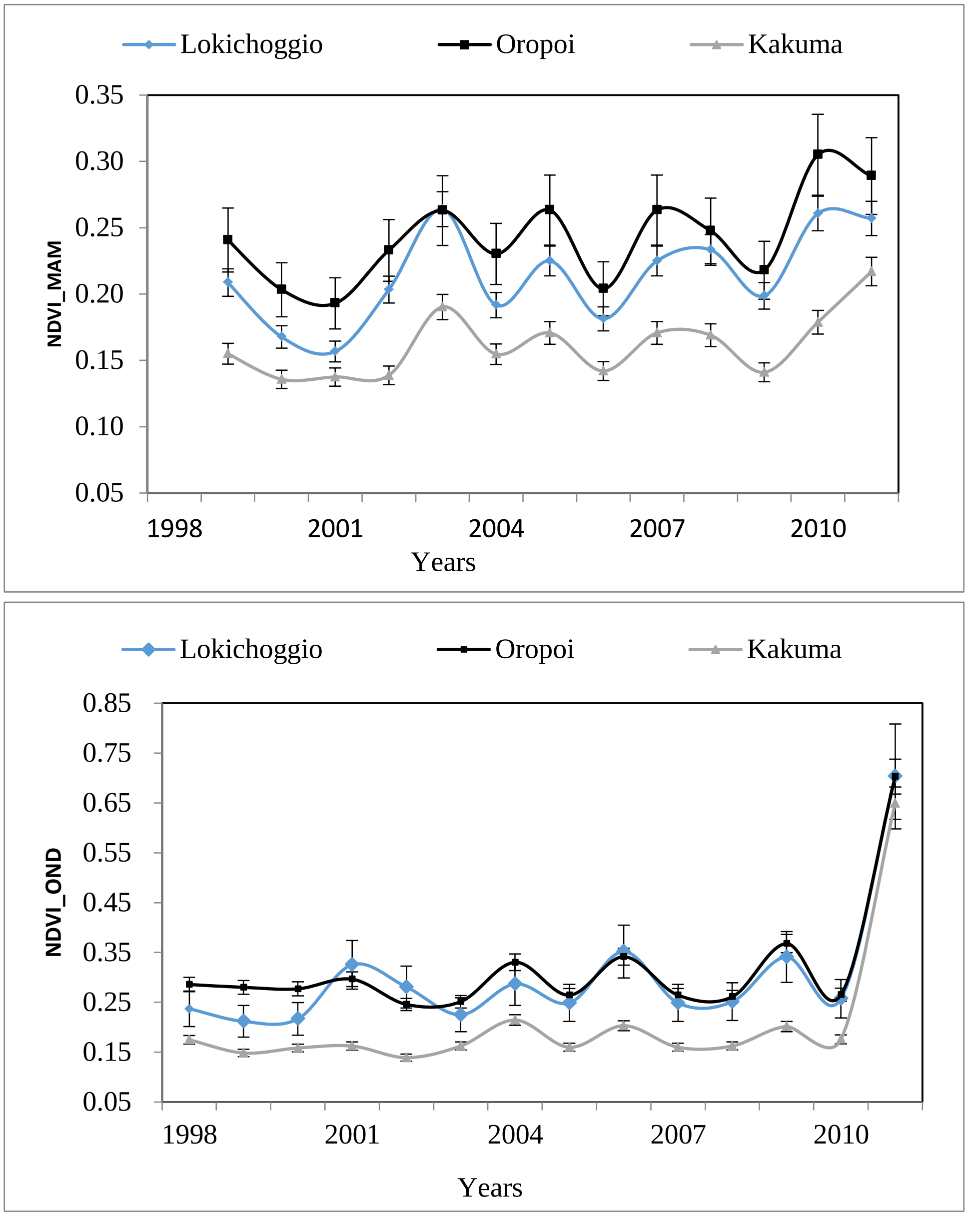
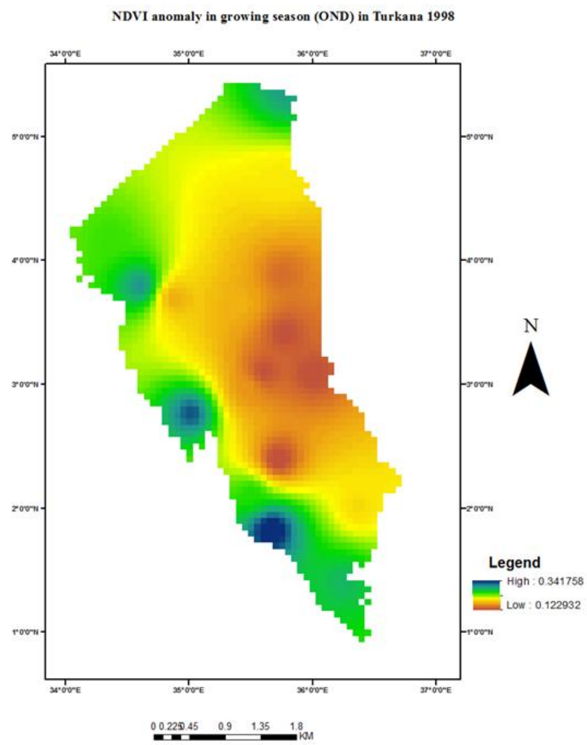


Figure 8.1 Average March-May (MAM) and October-December (OND) Normalized Difference Vegetation Index (NDVI) anomalies for Lokichoggio, Oropoi and Kakuma

Although MAM and OND are the main rainfall months, May and December are the peak NDVI months. Thus, after rainfall onset, there is a one month lag period for NDVI to reach its peak. A lagged effect of NDVI was also observed when MAM and OND rainfall showed high correlation values with April-June (AMJ) NDVI and November- January (NDJ) NDVI respectively. Overall, the response of vegetation was found to be strongest for OND precipitation anomalies than that of MAM seasons. The spatial NDVI anomaly patterns in Turkana are shown in Figure

8.2a, 8.2b, 8.2c, 8.2d and 8.2e. Between 1998 and 2010, a patchy pattern of below normal NDVI showed the prevalence of dry conditions across Turkana County, especially in the central region. Most of the pronounced greenness was concentrated in the western part along the border with Uganda. However, there seems to be light enhanced vegetation greenness with time. In other studies in similar ecosystems, Anyamba and Tucker (2005) reported a lagged response of rainfall and NDVI in Sahelian region between 1981 and 2003. Salim *et al.* (2008) found that vegetation response to North Atlantic Oscillation delayed by 1.5 years. In other regions in Africa, Martiny et al (2006) observed that the lag between the rainfall and NDVI peaks was smallest in western Africa with one month, and the highest in southern Africa with over 1.5 month, which was found to be related to the increased rainfall rate before the peak. The lag appear to relate to the fact that the vegetation does not respond directly to rainfall, but rather to soil moisture, which is a multi-months integral of rainfall (Malo and Nicholson 1990). The delayed effect of rainfall on vegetation anomalies has implications on the overall food web in the rangeland ecosystems (Holmgren *et al.* 2001). For pastoral communities in Turkana, this scenario is likely to have implications on planning and management of pasture resources. Funk and Brown (2006) have also used the lagged association between rainfall and NDVI to estimate vegetation response to current climatic conditions, helping to make early warning systems earlier for semi-arid communities in Africa.

Results of aggregate NDVI values show all the three locations have slightly enhanced green vegetation coverage during OND season than for MAM season. This could be attributed to more and reliable OND rainfall than MAM rainfall in north-western Kenya. Further, the result suggests a greater efficiency of the short rains in enhancing vegetation greenness compared with the long rains, a feature apparently undocumented in the existing literature. In contrast, previous studies by Coughenour and Ellis (1993) over north-western Kenya depicted Turkana sub-region as the most typical rainfall regime with low rainfall amount for the long rains and no obvious short rains, which implies a flat NDVI regime. The close coupling between seasonal rainfall and NDVI values has enhanced predictability providing a window of opportunity in planning for pastures and water resources in the rangelands. Seasonal variations in vegetation conditions can also be attributed to seasonal rainfall anomalies in other rangelands of eastern Africa. For instance, Martiny *et al.* (2005) demonstrated that for a given rainfall amount, the NDVI peak was comparatively higher for the short versus the long rains.



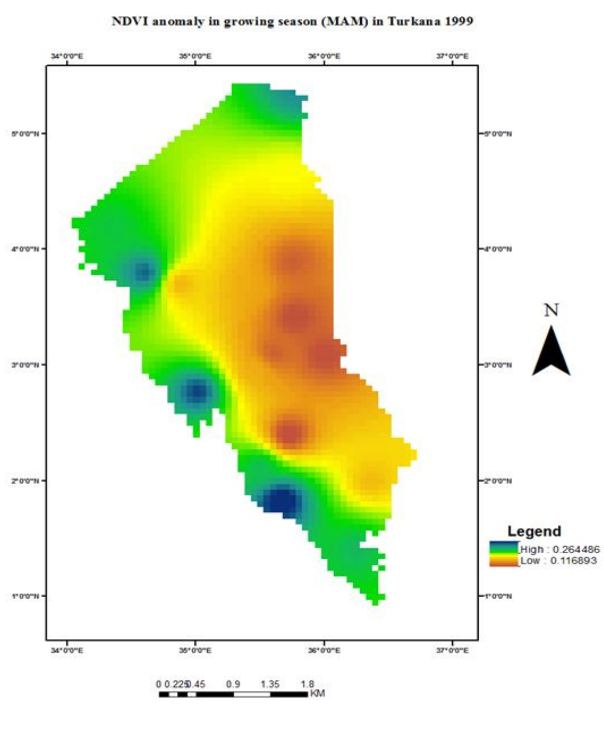


Figure 8.2a NDVI anomaly pattern in growing seasons OND and MAM for 1998 and 1999 respectively in Turkana County

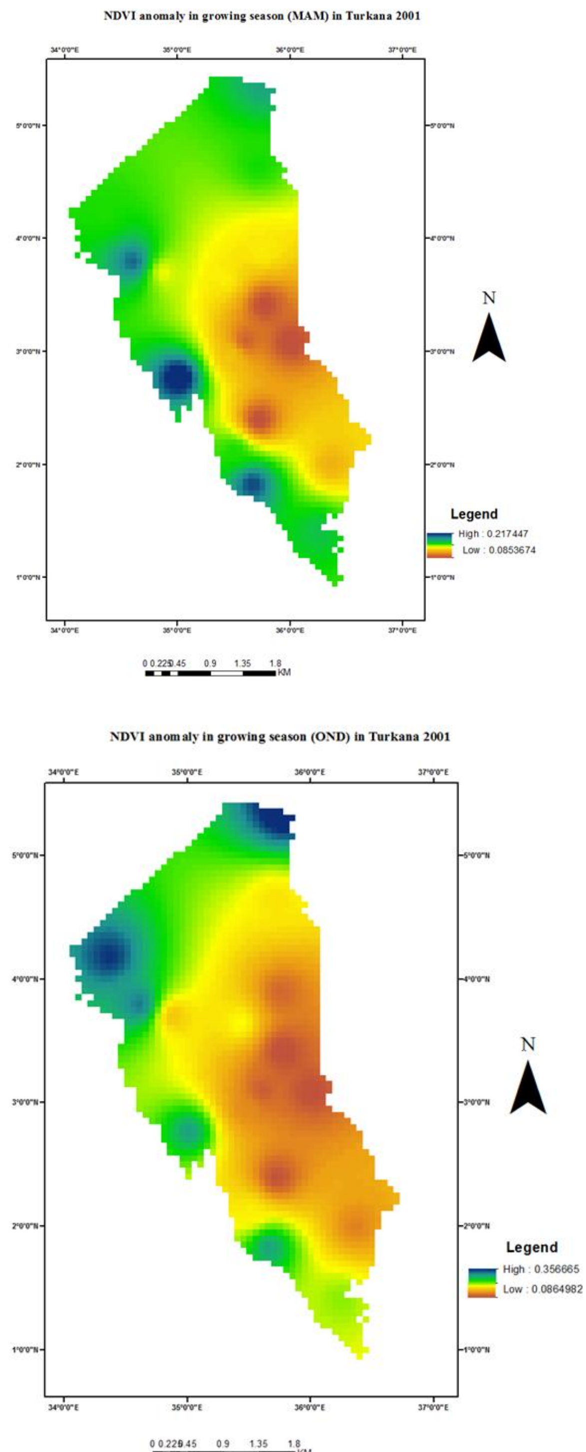
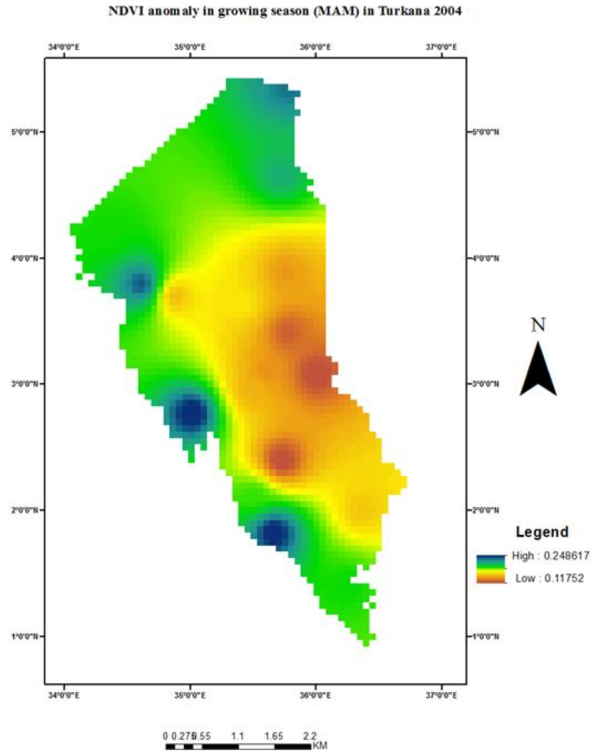


Figure 8.2b NDVI anomaly pattern in growing seasons MAM and OND for 2001 in Turkana County



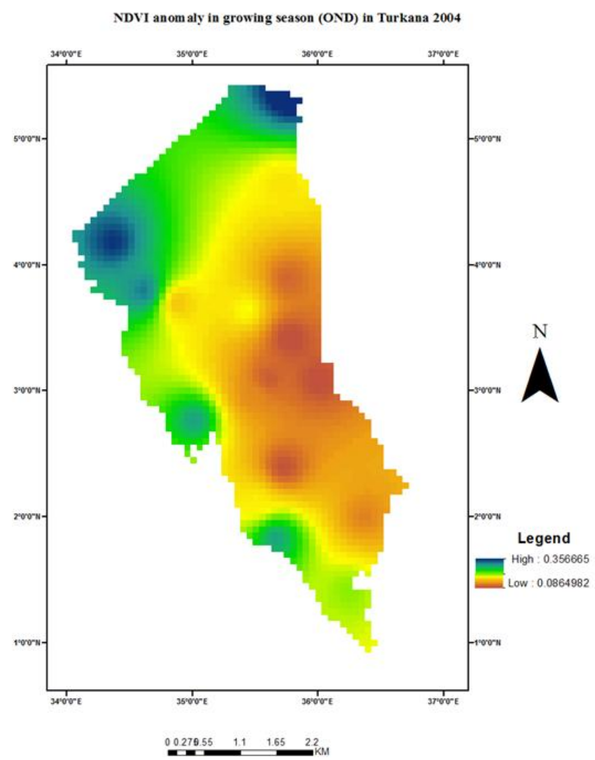
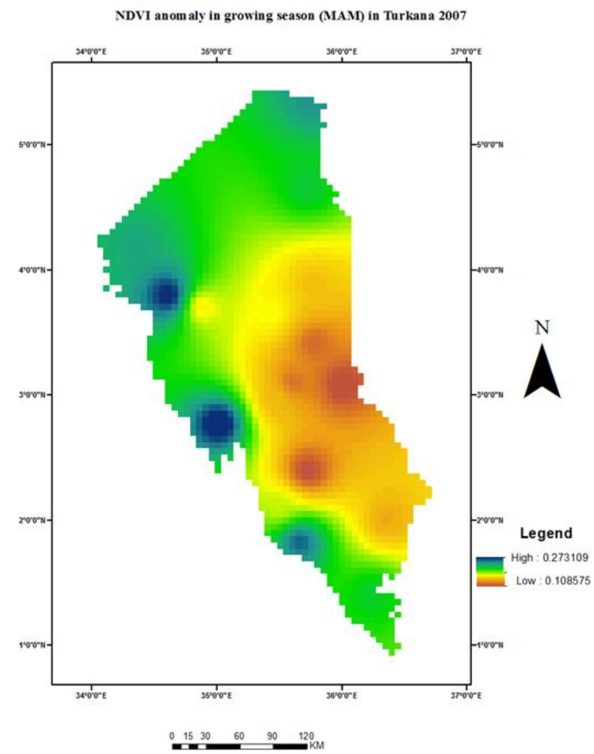


Figure 8.2c NDVI anomaly pattern in growing seasons MAM and OND for 2004 in Turkana County



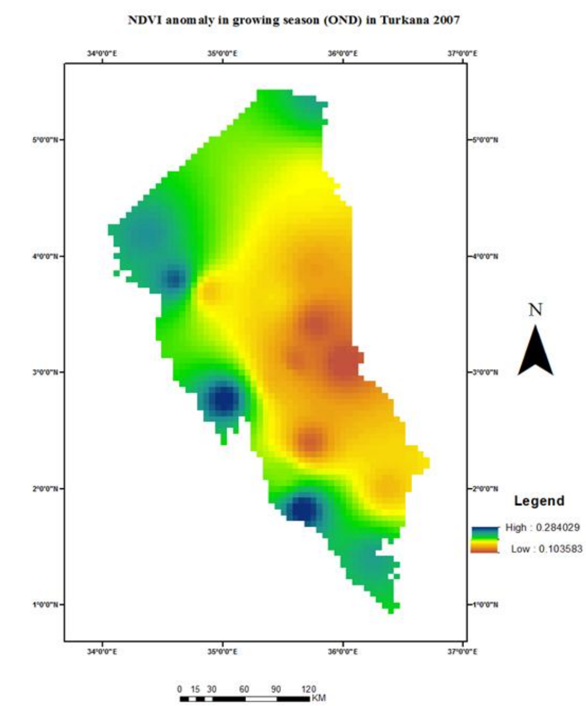
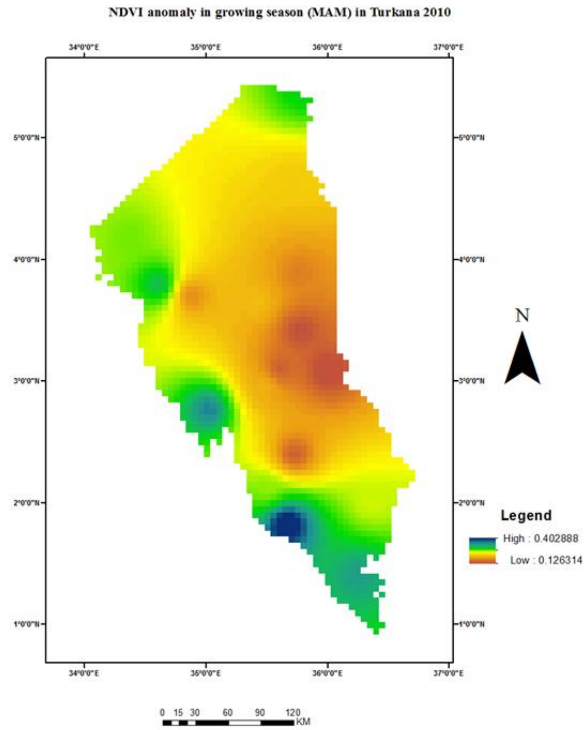


Figure 8.2d NDVI anomaly pattern in growing seasons MAM and OND for 2007 in Turkana County



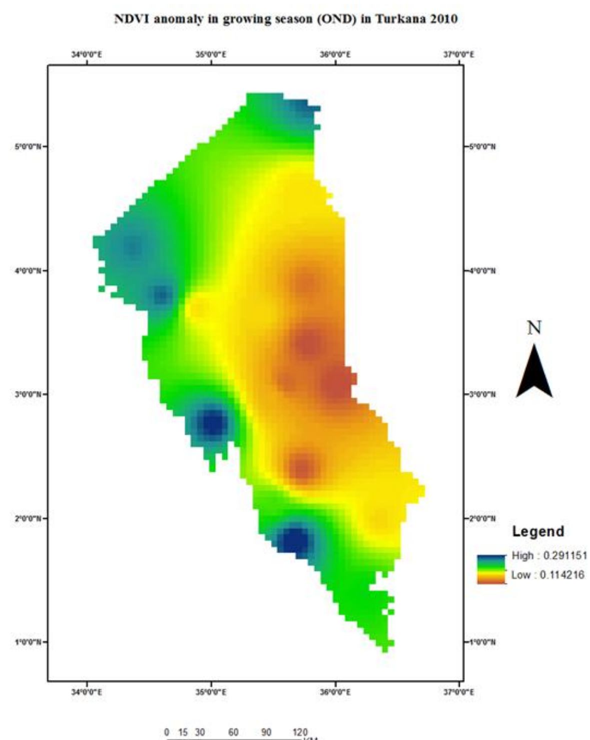


Figure 8.2e NDVI anomaly pattern in growing seasons MAM and OND for 2010 in Turkana County

The measurements of vegetation dynamics using NDVI values during the last 14 years in Turkana have provided a comprehensive picture of inter-annual, seasonal variation and trends. From the results, the persistence and spatial frequency of below normal rainfall conditions over the last decade is well represented by the NDVI anomaly patterns across the area during this study period. In general, the time series trends in NDVI indicate a greening pattern across the three locations with the most systematic pronounced increases in Oropoi. The persistent nature of the seasonal effect on NDVI between 1998 and 2011 is in agreement with the historical patterns of rainfall anomalies observed in other parts of Kenya by Shisanya *et al.* (2011). However, what the NDVI time series data suggest is that there is a gradual and slow but persistent vegetation recovery in parts of the area, especially in Oropoi and parts of Lokichoggio on north western side bordering Uganda. This is corroborated by the decrease in magnitudes of negative NDVI departures from long term mean between 2009 and 2011 (Figure 8.3). For Kakuma, there was a persistent negative trend in the NDVI residuals. Here, vegetation greening has fallen behind what would be expected from the increase in rainfall. A hypothetical explanation of what might be interpreted as human-induced land degradation and neglect of sustainable land use practices due to high populations.

Overall, result indicates a strong correlation coefficient and significant relationship between temporal NDVI and OND rainfall in Oropoi ($r=0.55$, $p=0.04$) and Kakuma ($r =0.59$, $p=0.03$), while Lokichoggio ($r=-0.17$, $p=0.57$) was not significant for the period 1998-2011. In contrast, the MAM seasonal correlation coefficient depicted weak and non-significant ($p<0.05$) relationship between NDVI and rainfall for the same period in Oropoi ($r=0.33$, $p=0.27$) and Kakuma ($r=0.43$, $p=0.12$), while Lokichoggio had strong and significant correlation coefficient ($r=-0.56$, $p=0.04$). The results suggest that approximately 30% of variability in vegetation greenness during the OND season could be predicted by rainfall variability especially in Oropoi and Kakuma. To some extent the 70% of variability in vegetation that is not explained by rainfall anomalies in Lokichoggio during the MAM rainy season could be as a result of other socio-economic land use practices in the area. From the correlation analysis, the association between NDVI and rainfall is better discussed for each individual station than for the entire study area. This is not surprising since the specific sites are more homogeneous than the multi-stations zone with respect to additional environmental factors such as topography, soil types and land use practices.

The findings suggests that areas with low mean annual rainfall of < 200 mm such as Oropoi and Kakuma depict a stronger and significant relationship between NDVI and rainfall compared to Lokichoggio with annual rainfall of >300mm. Previous studies by Nicholson *et al.* (1990) observed log-linear relationship between NDVI and rainfall in parts of the Sahel and East Africa. Despite the conflicting result in this study, the large scale and coherent changes in vegetation anomaly patterns over the past 14 years suggest some strong climatic influence on vegetation dynamics in Turkana. Nonetheless, the patchy nature of the increase in NDVI in the study area will require the use of higher spatial resolution data from LANDSAT, SPOT and MODIS in order to determine the driving factors of change at more temporal and spatial scale. It is suggested that further studies examining combined climate data including rainfall and sea surface temperature patterns and continued gathering of long-term satellite data sets is likely to help in understanding the long-term changes in the climate and land surface conditions of this sensitive in non-equilibrium environment.

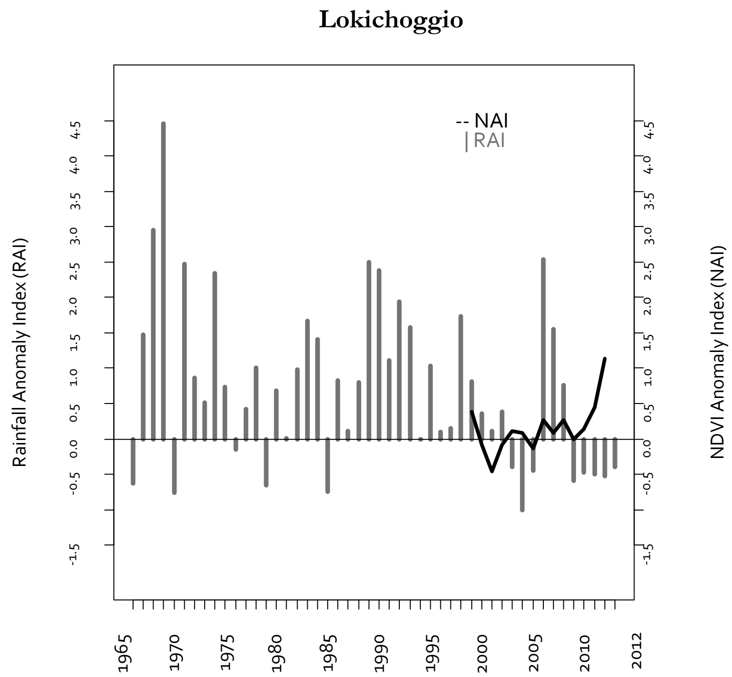


Figure 8.3a Comparison between seasonal rainfall (MAM & OND) anomaly index (RAI: 1965-2012) and NDVI anomaly index (NAI: 1998-2011) for Lokichoggio

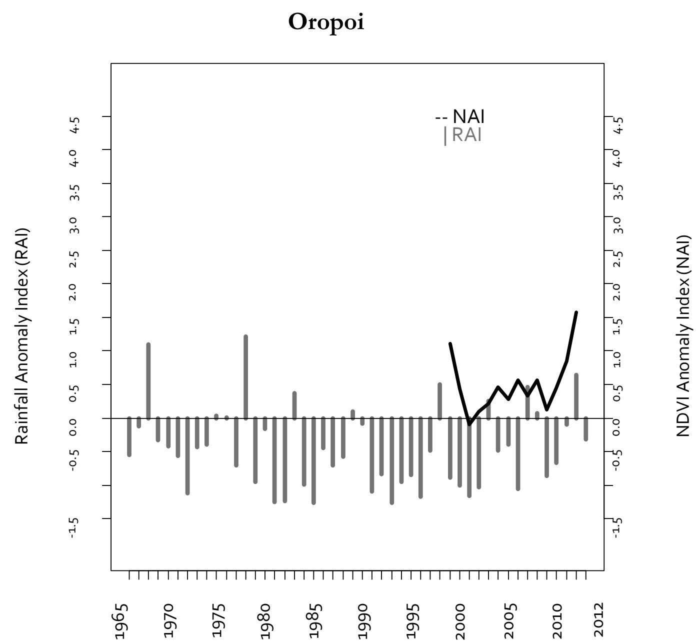


Figure 8.3b Comparison between seasonal rainfall (MAM & OND) anomaly index (RAI: 1965-2012) and NDVI anomaly index (NAI: 1998-2011) for Oropoi

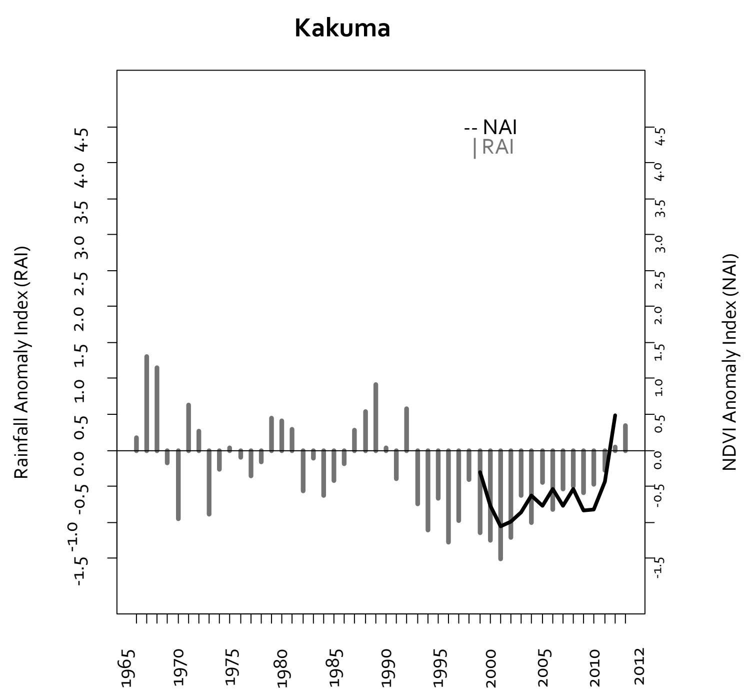
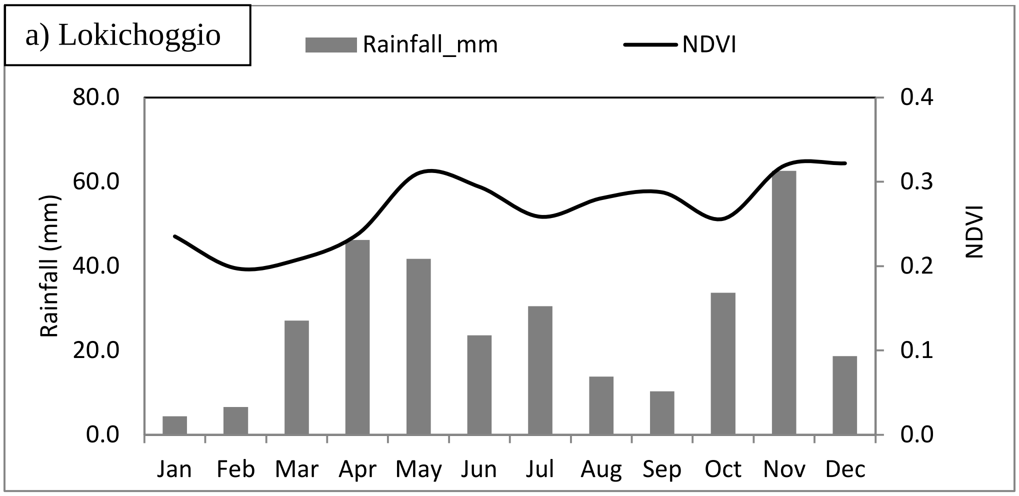


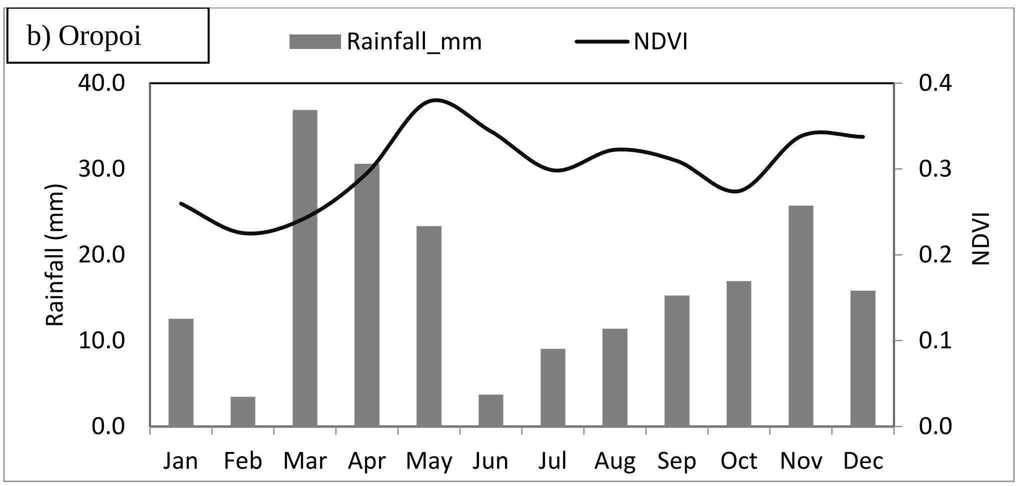
Figure 8.3c Comparison between seasonal rainfall (MAM and OND) anomaly index (RAI: 1965-2012) and NDVI anomaly index (NAI: 1998-2011) for Kakuma

8.3.3 Monthly time series anomalies

The average monthly time series of NDVI and rainfall for Lokichoggio, Oropoi and Kakuma for the period 1998-2011 are illustrated in Figure 8.4. On average most of the rainfall occurs in MAM and OND seasons in the study area. The rainy seasons makes a considerable contribution to the annual rainfall totals, so averaging NDVI data for these months fairly represent the growing season for the region. Results show that although April and November are the peak rainfall months in the study locations, May and December are the peak NDVI months (Figure 7.4). Thus, after rainfall onset, there is a one month lag period for NDVI to reach its peak. The lagged effect of NDVI was not observed in the Pearson's correlation results which revealed low correlation coefficient between MAM rainfall and April-June NDVI in Kakuma (r=0.38, p=0.21), Lokichoggio (r=0.28, p= 0.32) and Oropoi (r=0.42, p= 0.13). In contrast, the correlation between OND rainfall and November-January (NDJ) NDVI was strong and highly significant for Kakuma (r=0.58, p=0.02) and Oropoi (r=0.58, p= 0.03), expect in Lokichoggio (r= -0.214, p =0.46). The observed difference not explained by rainfall variability is probably due to vegetation types and land use activities in the study locations. In other studies, Malo and Nicholson (1990) suggested that the lag appear to relate to the fact that the vegetation does not respond directly to rainfall, but rather to soil moisture, which is a multi-months integral of rainfall. Previous studies by Anyamba *et al.* (2005) reported 1-3 months lagged response of rainfall and NDVI in eastern Africa after the 1997/ 1998 El Niño event. Similarly, Wang and You (2004) found that vegetation response to North Atlantic Oscillation delayed by 1.5 years.

The NDVI time series results show on average very low values from January to February and then afterwards increases and reaches a peak in either May or June before it starts decreasing up to August or September. This pattern clearly shows close correspondence of monthly rainfall anomalies with NDVI observed over a short period of time. It can be thus summarized that NDVI anomalies, which are a culmination of how environmental factors (soil moisture and temperature) act upon the land surface, have stronger linkages with monthly rainfall anomalies than any other climatic variable. Results from the study confirmed that good correlation occurred between average rainfall and NDVI for monthly data with a trend of increasing NDVI with rainfall. Overall, better correlation between rainfall and NDVI was observed in Oropoi and Kakuma than in Lokichoggio.





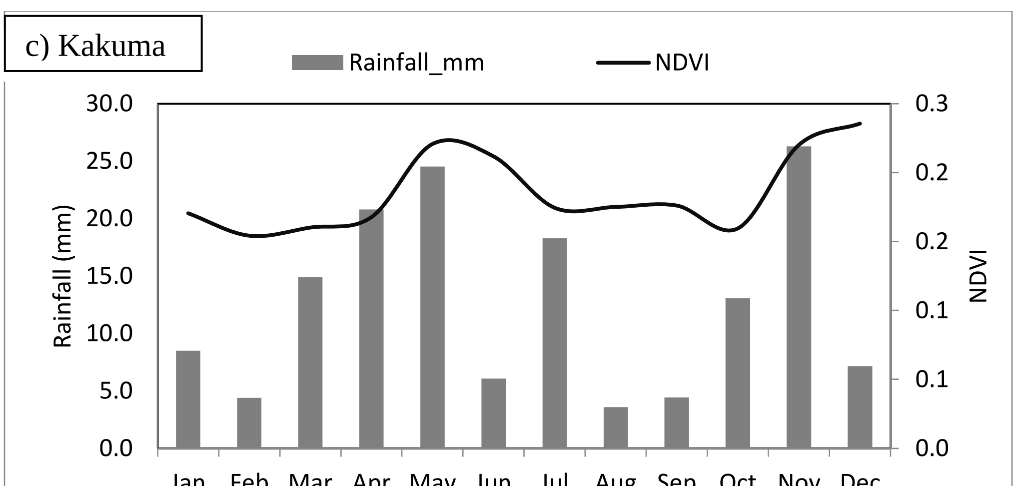


Figure 8.4 Influence of average monthly rainfall on NDVI at selected stations in (a) Lokichoggio, (b) Oropoi, and (c) Kakuma for the period 1998-2011

8.3.4 Ground truthing for vegetation species richness and abundance

Approximately, fifteen (15) tree species were recorded in the study area, out of which *Acacia reficiens* and *Prosopis juliflora* where the dominant species in all the sampled locations. Other tree species observed includes *Boscia coricea, Acacia mellifera Acacia nubica, Balanices spp, Acacia elation, Cadaba farinosa* and *Commiphora Africana* (Table 8.3). For the shrub and herbs, *Crotalaria fascuraris* was the most abundant across the selected study sites. Other herbs/shrubs scattered across the sampled locations were sisal species, *Sterculia Africana, Maema subcodate, Trichilia emetic, Aloe turkanensis* and *Indigofera spinosa* among others. Most of the open rangeland was devoid of grass species. However, during the field visits, the occurrence of bare patches, and glades of single grass species such as *Cenchris cilliaris, Eragrostis Superba* and *Trichollia emetic* were reported, although the composition was relatively low.

The vegetation diversity analysis using the Shannon diversity index (H) revealed a mean index of 3.8, which is a relatively high species richness and abundance in the study area (Table 8.4). The high species diversity indicates significance in conservation of genetic resources of woody species which are under heavy threat of local climate change and anthropogenic extermination. Furthermore, these species play an important role as source of forage for livestock and for other economic value. The increasing higher density of *A. reficiens* and *P. Juliflora* is an indicator of poor range conditions in Turkana. Frequent drought episodes, increasing human and livestock populations, and other anthropogenic activities exerting pressure on the vegetation resources could partly be linked to this poor range condition in the study area. This concurs with other previous studies that linked recruitment of *A. reficiens* and other invasive species in the rangelands to increasing poor conditions of the range (Coughenour *et al.* 1990).

The tree species richness and abundance significantly ($F_{(15, 41)} = 2.17$; $p = 0.025$) varied across the study locations accounting for 37% of the total variability. Similarly, for shrubs/herbs which varied significantly ($F_{(20, 41)} =1.88$; $p=0.043$) across the study locations. Results showed that Oropoi had the highest tree species richness and abundance followed by Lokichoggio and then Kakuma. By contrast, Lokichoggio had the highest shrubs/herbs species abundance. The study showed that areas with human settlements around urban centers, like Lokichoggio and Kakuma were heavily browsed and woody species harvested for firewood and charcoal burning. Some trees, for example *Acacia tortilis* and *Salvadora persica* were coppicing. These trees were also some of the most important sources of forage for livestock. In fact, unpalatable species dominate these areas. For example in Turkana, There was a high cover of unpalatable species near the settlement camp e.g. *Cadaba rotundifolia, Sanseveria spp* and *Euphorbia cuneata.*

Table 8.3 Vegetation species richness and abundance at Kakuma, Lokichoggio and Oropoi

Location	tree species	No. of plots species was found	frequency	% frequency	Mean stem density/ha
Kakuma	*Acacia reficiens*	5	13	42	260
	Boscia coricea	1	1	3	100
	Prosopis juliflora	3	17	55	567
Lokichoggio	*Acacia mellifera*	7	8	14	114
	Acacia reficiens	7	32	55	443
	Acacia tortilis	1	1	2	100
	Balanices spp	3	4	7	133
	Boscia coricea	5	6	10	120
	Cadaba farinosa	2	3	5	150
	dobera glabra	1	1	2	100
	Prosopis juliflora	2	3	5	150
Oropoi	*Acacia elation*	1	4	6	400
	Acacia mellifera	2	2	3	100
	Acacia nubica	2	13	21	650
	Acacia reficiens	6	20	32	267
	Balanices spp	2	3	5	150
	Boscia coricea	6	9	15	150
	Commiphora africana	2	2	3	100
	Corclia spp	2	3	5	150
	Merifera	1	1	2	100
	Prosopis fulifcora	1	1	2	100
	Salvadora persica	1	1	2	100
	Sisal	1	2	3	200
	Vangueria infausta	1	1	2	100

Table 8.4 Trees, shrubs and herbs diversity in Kakuma, Lokichoggio and Oropoi

Vegetation	Diversity test statistic	Diversity indices	Bootstrap estimate	Bootstrap S.E	95% Bootstrap CI
Tree species	Shannon-Weiner H	**3.8**	3.5	0.07	[3.4, 3.7]
	Q-statistic	14.6	20.6	3.66	[15.9, 30.3]
Shrubs/herbs					
	Shannon-Weiner H	**3.8**	3.6	0.08	[3.5, 3.8]
	Q-statistic	13.9	21.7	8.42	[14.9, 38.0]

*S.E - standard error, CI - confidence interval

Overall, the vegetation range condition was poor and likely to limit a number of adaptation and coping strategies used by the pastoralist in the area. The ground truthing findings validate the positive trend in vegetation greenness observed using the NDVI satellite data for the period 1998-2011 in Turkana. This study implies that the enhanced vegetation greenness observed is as a result of the transitions in vegetation cover from the bare 'sparse shrubs and sparse herbaceous' and 'grassland' to a more green coverage as a result of *P. Juliflora* invasion of the range. The invasive species have been recognized to have the most serious threat to biodiversity leading to habitat loss (Callaway and Aschehout 2000). In the study area, the increasing colonization of the range with invasive species is likely to have environmental and socio-economical threat, particularly to livestock production. This will ultimately limit the livestock-based adaptation strategies used by the locals to mitigate risk posed by increasing climate variability and change in Turkana. Some of the strategies likely to be compromised are livestock mobility, herd diversity, crop-farming and other nature based enterprises like mat-making. In addition, in some areas where the ground was bare and prone to wind and water erosion, there is likelihood of increased vulnerability to climate change as a result of respiratory diseases and erosion of scarce natural resources.

8.4 Conclusions

This study has shown positive trends in vegetation greenness over for the past 13 years (1998-2011) in Turkana. The increased vegetation greenness was partly associated with invasion of the rangeland by *P. juliflora*, as observed through ground truthing in the field. The use of NDVI as a proxy for vegetation conditions in more arid ecosystems (rainfall <200 mm/years) is recommended, since NDVI was more tightly coupled with precipitation in drier zones. The locations that were identified to be strongly sensitive to precipitation anomalies can be expected to be particularly prone to extreme climatic events like drought. Results presented in this study reinforce previous findings that temporal rainfall variability is persistent in the area and this will continue to impact on vegetation and with resultant effects on lives and livelihoods of the pastoralist who inhabit the study area. The transitions in vegetation cover from the bare 'sparse shrubs and sparse herbaceous' and 'grassland' to a more green coverage in the study area, though positive should be treated with caution. To improve the range condition, effective management techniques for invasive species should be in place. Herd mobility should also be encouraged to allow for restoration and regeneration of the degraded rangelands. As a result of shifting conditions, especially with the vegetation species richness and abundance, diversifying into livestock species that are browsers and are more drought-tolerant seems to be the appropriate adaptation strategy to changing climate and rangeland conditions in northwestern Kenya. Differences among the livestock species in terms of their feeding behaviors and tolerance to water and pasture shortages could enable herders to utilize more diverse ecological niches and serve as a buffer against increasing climate risks in addition to challenges posed by deteriorating grazing rangelands.

Finally, this study has demonstrated that monitoring vegetation dynamics from satellite data could lead to a better understanding of precipitation influence on vegetation resources in non-equilibrium ecosystems. Nonetheless, it was concluded that the observed NDVI trends in Turkana cannot be exclusively be explained by rainfall anomalies, since there are a number of anthropogenic factors that impact of vegetation dynamics. Thus, further research could focus on investigating climate variables and human-induced factors in vegetation variability, as well as long-term monitoring of the arid ecosystems.

CHAPTER NINE

SUMMARY CONCLUSIONS, RECOMMENDATIONS AND FUTURE RESEARCH

9.1 Summary Conclusions

This study has revealed that arid and semi-arid areas of Turkana are typified by high rainfall variability and uncertainty with episodic occurrence of uncharacteristic extreme droughts associated with changing climatic conditions. According to climatological analyses, there were more years with below normal rainfall, leading to the observed recurrence of multi-year drought events. The extreme drought events increased over the last 63 years, with 28.5% occurrences between 1950 and 1970, to 47.9% over the last two decades between 1990 and 2012. The climate variable observed provide incentives for debating on rainfall variability and by extension on climate change. This kind of scientific information is essential for timely adjustment to extreme climatic events, especially intermittent droughts that often plague the arid and semi-arid regions. The understanding of rainfall variability allows for targeting of specific interventions to avoid the waste of resources and effort currently represented by hasty and reactive interventions in arid and semi-arid regions of northern Kenya.

Further, this study have shown the area is warming at 0.13°C, with a significant ($p<0.05$) rise in both maximum (0.1°C) and minimum (0.2°C) temperatures for the period 1979-2012. The increases in temperature are in line with community perception on climate change in terms of warmer days, extreme droughts and increase in temperature. Majority (96.7%) of the household respondents, who perceived climate change, indicated that it leads to increase in livestock mortality, food insecurity/famine, pasture and water scarcity, decline in crop-productivity and increase in food prices. It is probably this rise in temperature observed that increases livestock heat stresses, resulting in a decrease in foraging time, thus low livestock productivity and eventually mortality. Information on how communities' perceive climate change could lead to a better understanding of possible interventions that suit pastoralists' needs and support them to adapt with climate variability and change.

According to the study results, majority of the pastoralists' will continue to be particularly vulnerable to extreme climate scenarios unless appropriate climate adaptation and coping strategies are strengthened. This study showed that households were moderately (44%) to highly (27%) vulnerable to climate induced stresses. The women headed households, household heads with no formal education, divorced and widowed household heads, households with no off-farm income sources, household who own less than 2 TLU and have no access to affordable credit facilities, and households with no access to information were the most vulnerable to climate variability and change in Turkana. Therefore, interventions that enhance opportunities for women's empowerment, and provide access to education and climate information, support herd mobility and income diversifications, besides access to affordable credit and markets are necessary for climate resilient households. However, because of other factors such as widespread poverty (87.5%), violent conflicts, livestock disease outbreaks and land degradation in the area that compound pastoralists' vulnerability to climate change; it is imperative that practical adaptation actions targeting the vulnerable should focus on these social, economic, political and biophysical factors that reinforce each other to undermine pastoralist resilience to extreme climatic events.

Vegetation resources will continue to be key resource around which resilience to climate variability and change will be build. In this study, use of NDVI could lead to better understanding of vegetation changes in more arid environment with rainfall amount of less than 200 mm/year. The reported shift in vegetation composition to species such as *P. juliflora*, *A. reficiens* and *Salvadora persica* in Turkana has a corresponding influence in livestock species kept. In clonclusion, the findings of this study have contribute to a better understanding of households' vulnerability to climate variability and change, this provides information for supporting adaptation interventions, particularly on how pastoralist can take advantage of the heterogeneity of the arid and semi-arid environments.

9.2 Recommendations

This study has demonstrated that pastoralists' vulnerability has been significantly affected by climate variability and change in Turkana. The research revealed that household-level strategies for adapting to climate change and variability are constrained by frequent droughts all compounded by widespread poverty, violent conflicts, and diseases outbreaks and poor range conditions in Turkana. From this study a number of recommendations can be suggested. These include:

- The integration of indigenous households' perceptions of climate variability and change with scientific meteorological data on rainfall and temperature trends are necessary for better planning and targeting of interventions.

- There is a need to support pastoralists' adaptation and coping strategies to overcome future scenarios of climate variability and change. More efforts should focus on reducing climate risk and expanding opportunities for diversification of livelihoods, safe livestock mobility and herd diversification. Furthermore, interventions that promote women empowerment, support education, enhance access to markets and climate information are necessary for climate resilient households in Turkana.

- To improve the national and county government engagement on climate variability and change, there is need to systematically review current plan and strategies to assess the synergies and gaps on climate change adaptations at a more local level. The fragmentation and privatization of rangelands which threaten sustainability of pastoral mobility need to be addressed in the policy documents. At the national level, there is also disparity in the legislation of climate change policy based on the draft Climate Change bill which need to be enacted to set legal and institutional framework for ensuring mitigation and adaptation to the impacts of climate variability and change in Kenya.

- The use of NDVI as a proxy for vegetation response to precipitation anomalies is recommended for more arid ecosystems with rainfall amount of less than 200 mm/year. This, however, require field validation of the vegetation types as increase in vegetation greenness of invasive species could be confused for improved range conditions.

- It was observed during the fieldwork that the grazing areas are increasing being colonised by the invasive *P. Juliflora* and other Acacia spp. bush encroachment. The indigenous grass species – *Cenchrus ciliaris* and *Eragrostis superba* are quickly disappearing. The management needs to explore ways of controlling invasive species and de-bushing the rangelands. Diversifications of livestock herd with more browsers – goats and camels would also be appropriate to enhance pastoralists' resilience to drought and heat stresses in Turkana.

9.3 Future Research

More research is required to strengthen the basis of decision-making and generate more information to guide programming and enhance understanding on climate variability and change in the arid and semi-arid environments. The future research areas include but not limited to the following:

- Further research to ascertain the underlying factors influencing the climate of Turkana, causes for the differences in monthly mean temperature, actual effects of ENSO on rainfall totals and the influence of Indian Ocean over northern Kenya. At the same time aspects of the impacts of changing land use patterns, degradation and global warming on the micro-temperature also require more consideration in future research.

- An in-depth study that builds on the present findings to document similarities and differences in spatial-temporal rainfall and temperature trends using datasets from more than one Meteorological stations in Turkana County is recommended. Further research is also required to identify and understand physical factors which affect the year-to-year and seasonal variability in the drylands. This understanding would be a pre-requisite for improving rainfall early warning predictions.

- The increasing use of charcoal burning and firewood harvesting in Kakuma, Lokichoggio and Oropoi as coping strategy by the Turkana community need to be understood better in terms of socio-economic and ecological sustainably especially with the challenges of future climate scenarios. Research may also needs to investigate the trade-offs to better understand the effects on other ecosystem services in Turkana.

- In this study, the causal relationships between significant variables and outcomes in terms of vulnerability levels are explained using existing literature. However, some of these explanations are rather speculative and not confirmed by scientific findings. More in-depth qualitative fieldwork with selected households based on these factors could strengthen factors confidence in some of the explanations given. The combination of quantitative surveys with qualitative approaches is likely to provide much more in-depth analysis of determinants of vulnerability.

- Influence of annual and seasonal rainfall on NDVI trends is explained in this study, however, it was concluded that the observed vegetation greenness anomalies in Turkana could not exclusively be explained by rainfall data. Thus, there is need to develop a robust approach that could distinguish between climate-induced vegetation variability and other anthropogenic factors in arid environments.

- The relationship between human activities and climatic factors and current vulnerability and resilience of pastoralist livelihood need to be ascertained.

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ANNEX 1 Household survey questionnaire

Household Characteristics

1. Date of Interview:	2. Questionnaire No.
3. County:	4. Name of respondent:
5. Sub-location/Village:	6. Location:

7. What is the gender of the head of household? Male (1) Female (0)

8. Age of the household head? (1) 18 – 30yrs, (2) 31 – 50yrs, (3) 51+yrs, (4) don't know

9. How long have you lived in this village? What is your household size?

How long have you lived in this village?	(√)	What is your household size?	(√)
(1) Less than five years		(1) 1 – 5 persons	
(2) 5-10 years		(2) 6 – 10 persons	
(3) 11-15 years		(3) 11 – 15 persons	
(4) Over 16 years		(4) >16 persons	

10. What is the highest level of education for the household head in terms of number of years in school? (√ as appropriate)

0 yrs	No formal education,	
8yrs	Primary education	
12yrs	Secondary education	
14yrs	Tertiary education,	
16 yrs	University education	

11. What is your marital status?

(1) Single/never married
(2) Married
(3) Divorced/separated
(4) Widowed
(5) Complex

12. How many persons in each age bracket? (0)>15yrs………, (1) 5-14yrs…………, (2) 0 - 4yrs…………….,

13. What is your household's main source of income? (1) farm based, (0) off-farm

Farm based	How much per month? Kshs	Off/Non- farm based	How much per month? Kshs
Livestock farming		Micro-business/small-scale	
Crop farming		Casual labour	
Crop and livestock farming		Artisan	
Others (specify)		Salaried/fixed employment	
		Charcoal burning	
		Fishing	
		Mixed (specify) …………………	

14. What are the other sources of household's financial support? (0) none, (1) children, (2) relatives (3) friends CBOs and NGOs, (4) government

15. Do you receive any regular financial support/ cash transfers? yes (1), no (0)

16. If yes, what is the source of cash transfer? (1) Government, (2) NGOs, (3) financial institution, (4) other specific……………………………………………………………..

17. If yes, how often do you get the cash? (0) fortnight, (1) monthly, (2) after two months, (3) others specify…………………………………..

18. What is your household average expenditure per month?

(1) <2,500 Kshs, (2) 2,500 – 5,000Ksh (3) 5,000 – 7,500Ksh, (4)> 7,500Ksh, (5) not sure

19. What are the main items for household monthly expenditure?..

………
………
………
………
…………………………………………………………………………………

(1) Education, (2) Human health, (3) Veterinary services, (4) Food, (5) Fuel, (6) Rent, (7) Transport, (8) Investment in livestock, (9) Investment in other activities, (10) others specify……………………

20. Has any of your household member ever obtained credit facility in the last 4 weeks? yes(1), no (0)

If yes, what source? Government………………value (Kshs)……………
Relatives and friends……………………………value (kshs)…………….
Non-governmental organizations………………value (kshs)……………
Others (specify…………………………value (Kshs)………………………

21. What form was the credit? In kind (0)……, in cash value (1)………

22. Do you have any of your household members employed elsewhere? Yes(1), no (0)

23. If yes, type of employment; permanent (1), temporary (0), other (specify)…………………………………………………………………

24. Did your household receive any remittance during the last one month? yes(1), no (0)

25. If yes, how much did you received? (1) <2,000 Ksh, (2) 2,000 – 5,000 Ksh, (3) 6,000 – 8,000 Ksh, (4) >8,000Ksh

26. According to your own opinion do you think that your household enjoyed good social linkages with relatives? yes (1), no (0)

LIVESTOCK

27. Do you own livestock? yes (1), no (0)

Livestock	No. owned today?	No. born during last 4 wks?	No. sold during last 4wks?	Average price per animal sold (PPA)?	No. died last 4 weeks?	Main reason for death? 1= diseases 2= drought 3 = floods 4= conflicts 5= predation 6= slaughter	Trend in livestock numbers? 1= increased 2= decreased 3= same
Cattle							
Goats							
Sheep							
Camels							
Donkey							

Othes…							

28. What is the approximate distance to the nearest livestock market? (0) Less than 1km, (1) 1 – 2km, (2) 3 - 5 km, (3) 6-10 km, (4) > 10km

29. What are the possible reasons for selling your livestock for the last one month? (most to the least)

……
……
……
……………………………………………………………

a) drought, b) school fee, c) medication, d) buy food, e) veterinary services, f) cultural festivals, g) others- specify

30. Have you been visited by any livestock extension officer over the last one year? yes(1), no (0)

31. Do you have milking cow in your herd? yes (1) no (0), if yes

Animal	How many over the last 4 weeks?	What is the total amount of milk produced in 750ml bottle?........bottles	Total amount consumed by household? bottles	What is the total amount sold by household? bottle	What is the average price of milk per 750ml bottle? bottle
Cattle					
Goats					
Camel					
Sheep					
Donkey					
Others…………					

32. How much do you pay for water per herd size?

……
……
………………………………………...

CLIMATE CHANGE

33. Do you perceive that there is climate change in your area? yes (1), no (0)

34. If yes, please explain

……
……
……
……………………………………………………………

35. Have you noticed any changes in temperature and rainfall in your area? yes (1) no (0)

36. If yes, how can you describe the temperature changes?

(1) Increasing

(2) Decreasing

(3) No change

(4) Varies continuously

(5) Don’t know

37. If, yes how would you describe rainfall changes?

(1) Rainfall amounts: increased, decreased, same/unchanged, fluctuated, don’t know
(2) Rainfall spacing: widened, narrow, same, cannot tell
(3) Rainfall time (season): shortened, extended, same, cannot tell

38. Have you noticed any changes in the following indicators? if yes explain

Indicators	Yes (1)	No (0)	If yes? explain
Drought			
Floods			
Wind			

39. What are the coping strategies that your household used during the previous droughts? Explain and monitor to tick accordingly.

………
………
………
………
…………………………………………………………………………………

(0) did nothing, (1) sold livestock, (2) borrowed from relatives, (3) waited for food aid, (4) participated in cash/food-for-work, (5) ate less, (6) sought for wild fruits, (7) sought for off-farm employment, (1) Sold livestock, (2) received food aid, (3) ate less, (4)participated in food for work, (5) applied soil conservation schemes, (6) borrowed from relatives, (7) sort for off farm employments.

40. Indicate the year/period when major climate related hazards occurred?

Hazards	1 1	1 0	0 9	0 8	0 7	0 6	0 5	0 4	0 3	0 2	0 1	0 0	9 9	9 8	9 7
(0) flood															
(1) drought															
(2) hailstorm															
(3) diseases outbreak															
(4) other specify															

41. Were there any traditional (observable and non-observable) indicators suggesting there would be the disaster/hazard that year? yes(1), no (0)

42. If yes, which ones?

……

43. How did the disaster /hazard affect your household?

(1) Decline in crop yield……………………………………………………………

(2) Loss of income…………………………………………………………………

(3) Food insecurity/ shortage…………..…………………………………………

(4) Death of livestock……………………………………………………………….

(5) Decline in consumption……………………………………………………………

(6) Others (specify)…………………………………………………………………

44. What are the factors that you consider to influences your climate adaptation and coping process?

(1) Lack of climate information

(2) Lack of money

(3) Shortage of labour

(4) Lack of skills

(5) Lack of education

(6) Lack of alternatives

(7) Others (specify)…………………………………………………………

45. What are some of the traditional drought coping mechanism that you are still using?

(1) Herd mobility, (2) herd splitting, (3) different livestock species, (4) large herd size, (5) others……

46. Do you perceive that traditional coping strategies are affective? Yes (1), no(0),

47. Are you able to move your livestock freely to the traditional grazing areas? yes (1), no (0)

48. What challenges do you face during migration?

……

49. What is the property right regime for grazing lands/fields? (1) communal access (0) private

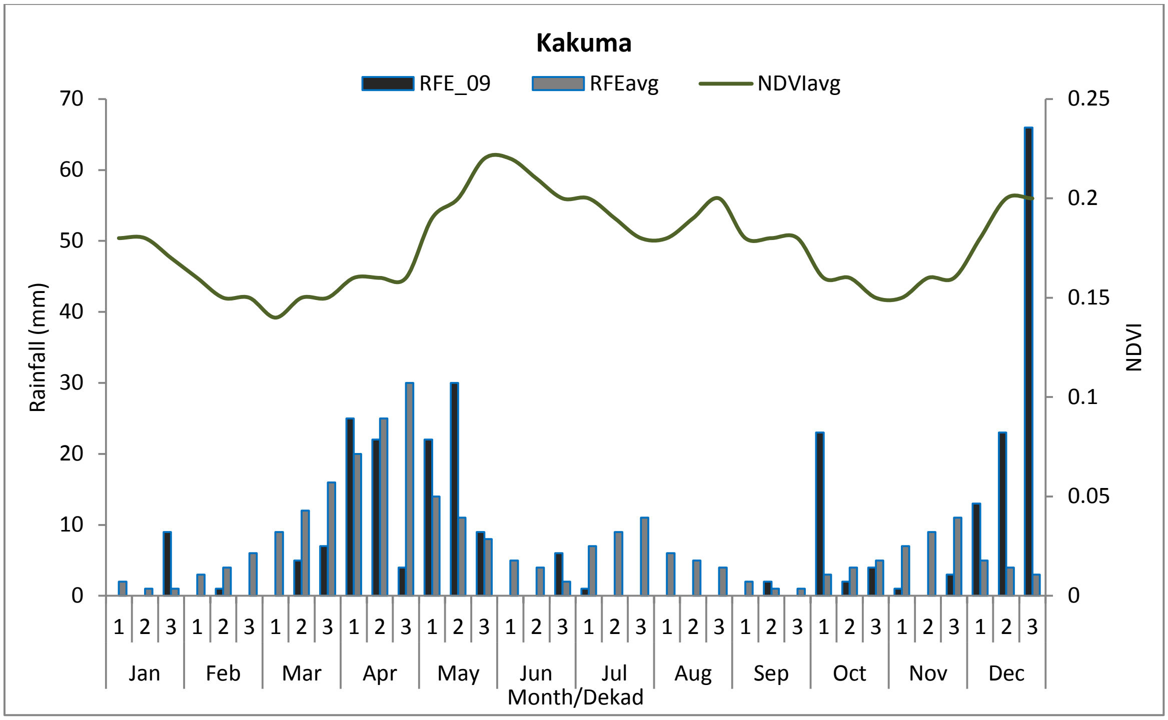
50. Measure the mid upper arm circumference (MUAC) of children older than one year but under 5 (U5) (12 – 19 months). Include quantifying children in the sampled household as well as the children in the neighboring household(s). Measure a minimum of 5 children. Name the child age in months- MUAC in millimeters (if possible to get accurate age include children who are able to walk but have MUAC shorter than ten centimeter).

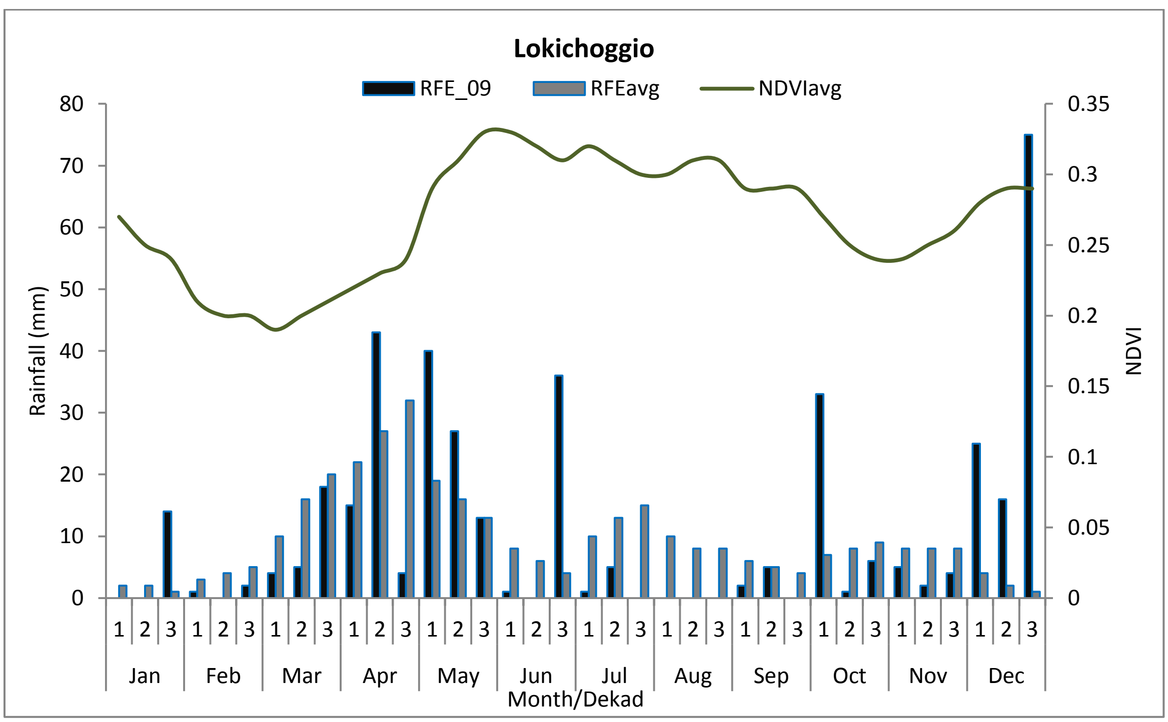
Name of the child	Age - months	MUAC - Millimeters
1		
2		
3		
4		
5		

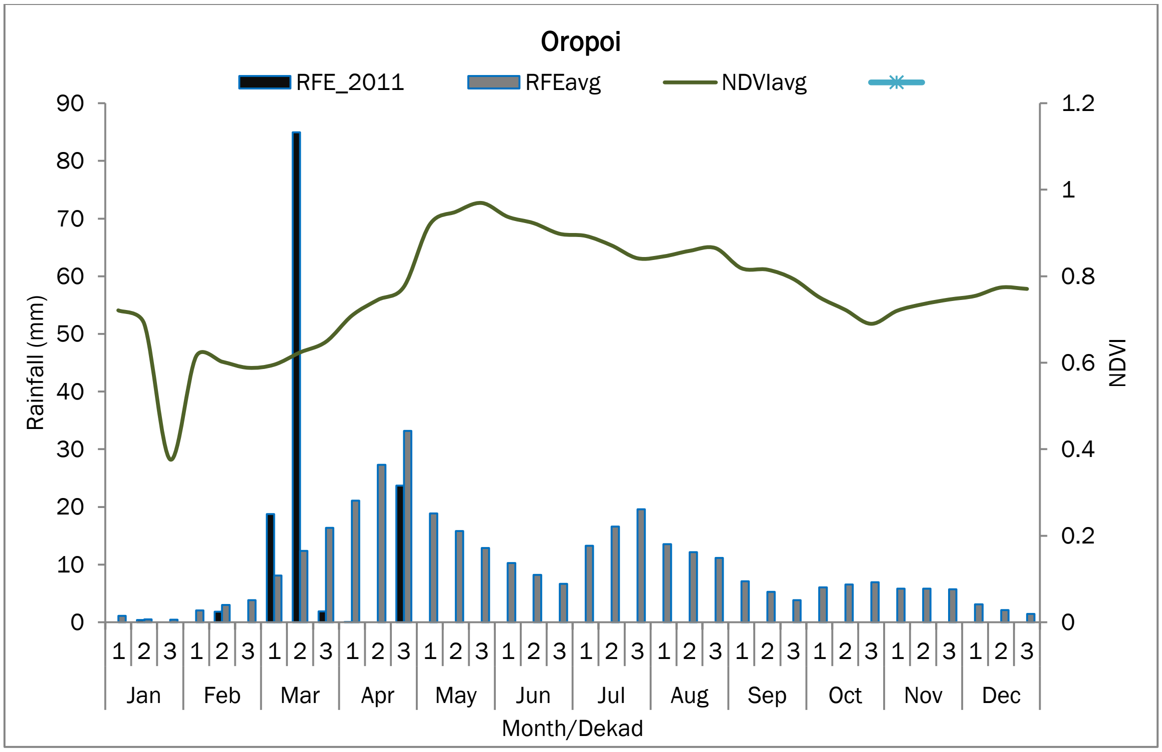
ANNEX 2 Shrubs and herbs distribution at Kakuma, Lokichogio and Oropoi

Location	Species	No. of plots species was found	Frequency	% frequency	Mean stem/ha
Kakuma	*Acacia paolii*	1	3	8	300
	Cadaba rotudifolia	1	5	14	500
	Crotalaria fascuraris	4	8	22	200
	Euphorbia magnicapsula	1	8	22	800
	Grewia villosa	1	9	25	900
	Indisofera spinosa	1	1	3	100
	Maema subcodate	1	1	3	100
	Prosopis juliflora	1	1	3	100
Kakuma total			11		327
Lokichogio	*Cadaba farinosa*	1	3	4	100
	Cadaba rotudifolia	2	1	1	150
	Crotalaria fascuraris	1	15	19	100
	Euphorbia spp	6	1	1	250
	Grewia tenax	1	7	9	100
	Indigofera spinosa	4	9	11	175
	Indigofera tintoria	6	1	1	150
	Indisofera spinosa	1	3	4	100
	Maema subcodate	1	7	9	300
	Omithogalum lenuifolium	4	2	2	175
	Sisal spp	1	2	2	200
	Solanum coagolans	1	1	1	300
	Sterculia africana	1	14	17	200
	Trichilia emetica	1	11	14	100
	Aloe turkanensis	3	1	1	467
	Prosopis juliflora	3	3	4	367
Lokichogio total			37		219
Oropoi	*Cadaba farinosa*	1	1	3	100
	Cadaba rotudifolia	1	1	3	100
	Combaetum aculeatum	1	1	3	100
	Euphorbia spp	2	2	5	150
	Grewia tenax	3	3	8	167
	Indisofera spinosa	2	5	13	250
	Maema subcodate	2	5	13	250
	Sisal spp	3	15	39	500
	Wild sisal	1	5	13	500
Oropoi total		16	16		256

ANNEX 3 NDVI and rainfall anomalies






Oropoi
RFE_2011
RFEavg
NDVIavg
Rainfall (mm)
NDVI
90
80
70
60
50
40
30
20
10
0
1.2
1
0.8
0.6
0.4
0.2
0
1 2 3 1 2 3 1 2 3 1 2 3 1 2 3 1 2 3 1 2 3 1 2 3 1 2 3 1 2 3 1 2 3 1 2 3
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month/Dekad

ANNEX 4 Livelihood zones in Turkana County