DROUGHT, LAND USE CHANGE AND LIVELIHOOD DIVERSIFICATION AMONG PASTORAL COMMUNITIES IN OLTIASIKA, KAJIADO COUNTY, KENYA

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A Thesis Submitted in Fulfillment of the Requirements for the Award of the Degree of Doctor of Philosophy (Environmental Planning and Management) in the School of Environmental Studies, Kenyatta University

November 2018

DECLARATION

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

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DEDICATION

This thesis is dedicated to those striving to curb climate change and extremes in order to safe Mother Earth.

ACKNOWLEDGEMENTS

This work would not have been accomplished without the support of various people and institutions. Special thanks to my supervisors, Prof. Simon Onywere and Prof. Chris Shisanya, for guiding me through this research. Their wise comments, critique and advice helped me shape the thesis. Special thanks also go to my colleagues at the Kenya Institute for Public Policy Research and Analysis (KIPPRA) for their encouragement.

I am also indebted to the Executive Committee of Mbirikani Group Ranch for its support in providing information and supporting my fieldwork. I am grateful to Solomon Kirisia, Faith and Bexton for their assistance in data collection and arranging for Focus Group Discussions. Special thanks go to the staff at Kenyatta University's Department of Environmental Planning and Management (EPM) and especially the team at the EPM Studio for their support with data coding and map generation. Special thanks also go to Victor Akoth and Alex Asige for their support on geospatial analysis. I pay tribute to the University of Natural Resources and Life Sciences (BOKU), Vienna, Austria and the National Drought Management Authority (NDMA), Kenya for availing Satellite Normalized Difference Vegetation Index data used in this study.

My sincere appreciation is extended to my wife Felly Kemunto, son Eliud Misati and daughters Rachel Kerubo and Abbygael Moraa for their moral support throughout the period of this study. Finally, I am grateful to my heavenly Father for seeing me through this journey and for His faithfulness and mercy.

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ABBREVIATIONS AND ACRONYMS

ASALs	Arid and Semi-Arid Lands
AVHRR	Advanced Very High-Resolution Radiometer
CFSR	Climate Forecast System Reanalysis
CLRCs	Community Learning Resource Centres
CRED	Centre for Research on the Epidemiology of Disasters
DFID	Department for International Development
DPSIR	Driving force – Pressure-State – Impact -Response
EDE	Ending Drought Emergency
EEA	European Environment Agency
EMCA	Environmental Management and Coordination Act
EPI	Expanded Programme on Immunization
EVI	Enhanced Vegetation Index
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
GIS	Geographic Information System
GoK	Government of Kenya
GPS	Geographic Position System
HHI	Herfindahl-Hirschman Index
ICM	Integrated Coastal Zone Management
IPCC	Inter- Governmental Panel on Climate Change
KII	Key Informant Interview
MODIS	Moderate Resolution Imagining Spectro-radiometer
MTP	Medium Term Plan
NACOSTI	National Commission for Science, Technology and Innovation
NCCAC	National Climate Change Activities Coordination Committee
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
NEMA	National Environment Management Authority
NFNP	Non-Farm Non- Pastoral
NIR	Near Infrared
NOAA	National Oceanic and Atmospheric Administration
NPF	Non-Pastoral Farm

ODI	Oversees Development Institute
OECD	Organization for Economic Cooperation and Development
OLR	Ordered Logit Regression
PSDI	Palmer Severity Drought Index
RA	Research Assistant
SES	Social Ecological System
SLF	Sustainable Livelihood Framework
SPI	Standardized Precipitation Index
SWAT	Soil and Water Assessment Tool
UNDP	United Nations Development programme
UNECA	United Nations Economic Commission for Africa
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
VCI	Vegetation Condition Index
VI	Vegetation Index
WCED	World Commission for Environment and Development
WMO	World Meteorological Organization
WRCC	Western Regional Climate Centre

ABSTRACT

This study investigated the implication of drought and land use changes on pastoral livelihood in Oltiasika area of Chyulu-Amboseli ecosystem. The study objectives were to assess the relationship between drought and vegetation conditions, assess biophysical changes that have occurred in Oltiasika between 2009 and 2016, and analyse the effect of livelihood diversification on household drought resilience. Rainfall data was obtained from Soil and Water Assessment Tool (SWAT) climate database, Moderate Resolution Imaging Spectro-radiometer (MODIS) Normalized Difference Vegetation Index (NDVI) data was obtained from the University of Natural Resources and Life Sciences (BOKU) in Vienna, while land use changes detection was analysed using Google Earth images. Primary data was generated through a cross-sectional survey carried out in January-February 2015 in a sample of 354 households. Auto regression analysis of Normalized Difference Vegetation Index (NDVI) and Standardized Precipitation Index (SPI) was carried out to investigate the relationship between drought and vegetation greenness. Herfindahl-Hirschman Index was computed to measure the degree of household livelihood diversification and Ordered Logit Regression analysis was performed to examine the effect of diversification on household resilience. The results showed that between 1983-2014 145 months were categorized as drought based on their Standardized Precipitating Index (SPI). Months with severe drought (SPI value between -1.50 and -1.99) were the most common (69 months) followed by those with mild drought (SPI ranging between 1-.00 and -1.49) in 57 months, while extreme drought (SPI less than -2.00) occurred in 19 months. The vegetation greenness for the period 2000-2016 produced Normalized Vegetation Difference Index (NDVI) with a mean of 0.34, which is below the normal mean (0.5). The driest period in the area was observed in September 2004 when the NDVI value was 0.193, while the wettest was in December 2006 with NDVI value of 0.62. The study found a significant relationship between NVDI and SPI with an R^2 of 59.6% and revealed that vegetation condition responded positively to drought with a lag period of two months. In the sampled sites between 2011 and 2016 the area under cultivation increased by 707% while the number of Manyatta settlements increased by 37.5%. Results of the Herfindahl-Hirschman Index showed that 22.73% of the households had an index of less than 0.25 and only 2.84% had an index greater than 0.5. Further, household's capacity to meet food requirements decreased with age and household size, while, education, total assets and net non-farm income had no effect. A unit change in the degree of diversification was associated with a 17.1% more likelihood for a household to fall in a strong category to meet food requirement, a 13.5% less likely to belong to a moderate category and 9.2% less likely to fall in a low category. Biophysical changes taking place in the area had limited the availability and accessibility of pasture upon which pastoralism thrive. While crop farming may provide answers to the immediate challenges confronting pastoral communities, the prevailing cultural and physical limitations makes this livelihood an ecologically destructive system. Pastoralism remain the most suitable livelihood activity in dry lands and adaptation actions, which complement rather than substitute it, should be encouraged.

CHAPTER ONE
INTRODUCTION

1.1 Background to the Problem

Pastoralism is a livelihood system common in places too dry for rain-fed agriculture and which experience frequent drought and strong climate variability. This livelihood system requires vast land and some degree of herd mobility for livestock to access sparsely distributed forage (Press, 2018; Galvin *et al*., 2001). To most pastoral households livestock is an important source of income and food security and access to forage and water is therefore essential (Breuer, 2007). In Africa, about 40 per cent of land is dedicated to pastoralism while in the Horn of Africa it – ranges from 95 per cent in Somalia to more than 80 per cent in Kenya, 60 per cent of Uganda, and approximately half of Tanzania (Njiru, 2012; Kandji, 2006). The areas support livestock rearing, tourism, and wild resource harvesting and an important source of national food security (Nori and Davies, 2006). High inter-annual rainfall variability, degraded ecosystems, and limited potential for arable farming are key characteristics of drylands, classified as arid and semi-arid lands (ASALs).

Demand for livestock products is projected to increase over the next few decades leading to intensification of agricultural systems in many ASALs (Thornton et al., 2018). At the same time, many pastoral communities are faced with the challenge of shift in land tenure policy from communal to individual landholding coupled with high in-migration rates (Kristjanson et al., 2002). Sedentarization and range fragmentation due to changing land tenure have restricted livestock mobility resulting in all season grazing that exerts pressure on certain grazing patches contributing to degradation. Declining land productivity, shrinking grazing areas, restricted movements, and the recurrent droughts have pastoralism (Hobbs et al., 2007) resulting in increased poverty and vulnerability of pastoral households and erosion of their capacity to cope with future shocks. Dryland change is exacerbated by continuing rise in global temperature due to climate change (IPCC (Intergovernmental Panel on Climate Change) 2001, Stainforth et al., 2005). Changes in vegetation availability associated with reduced mobility bode poorly for pastoral food secure especially in landscapes with insufficient productivity (Boone, 2018). A combination of land use and drought in drylands have constrained mobility of herders denying them a key coping strategy under high risk and uncertainty conditions (Little and McPeak, 2014). Thus, while some pastoralists have remained livestock-dependent others have diversified to agro-pastoralism or away from natural resources-based livelihoods to non-farm activities (Homewood, Kristjanson, & Trench, 2009). Consequently, a new form of pastoralism in emerging, one characterized by loss of land, resource degradation, restricted movement, encroachment of rangelands, and growing populations (Greiner & Mwaka, 2016).

Kenya’s drylands, defined as areas receiving annual rainfall below 1,000 mm and receive low but erratic rains, lasting short duration but often of high intensity and therefore highly erosive (Irungu et al. 2014; Gikaba et al. 2014). These areas are home to 14 million people and 70% of the total country’s livestock population (Omolo, Kikade, 2016; MacOpiyo et al. 2013). Drought and occasional floods are defining features of these drylands. The soils are generally poor, with high sand content, poor surface structure due to erosion and often saline with low organic matter (Gachathi, & Eriksen, 2011).

Recurrent drought, population increase and land use changes have significantly contributed to degradation and loss of natural pastures (Wasonga 2009; Munyasi et al. 2012). Consequently, large grazing lands have become bare and/or infested with invasive species affecting forage availability (Kidake et al. 2016; Vicente-Serrano et al., 2013). Being a common occurrence in pastoral systems, most communities have developed strategies to adapt to deleterious effects of drought (Mogotsi *et al.*, 2013), including diversification of livelihoods (Little et al. 2001; McCabe et al. 2010). While some form of livelihood diversification can increase pastoralists’ resilience (Ellis 2000; Barett et al. 2001; McCabe 2003), others can increase their vulnerability (Pedersen and Benjaminsen 2008). Farming is often the first livelihood strategy that traditional pastoralists diversify into (Little et al. 2001; McCabe 2003). The strategy has been utilized despite inadequate environmental variables for rain-fed cultivation in these arid areas.

The human-drought-livelihood nexus is best epitomized in Kenya's savannah recognized as one of the most vulnerable and drought-prone regions in the country (Nkedianye *et al*., 2011). With climate change, ASALs continue to experience frequent climatic extremes, increased aridity and water stress, diminished yield from rain-fed agriculture, and increased food insecurity and malnutrition (Thornton and Lipper, 2014). The inter-drought recovery period has also declined and exacerbated vulnerability of communities to subsequent drought. The Savanna rangelands of Kajiado County, home to the Maasai pastoral community have experienced rapid changes in land policies that have transformed former pastoral communal lands into individual ranches and private holdings, associated with a number of land-use systems (Kristjanson et al., 2002; Mwangi, 2007). Land use changes are driven by demographic changes (local population growth and migration), economic changes (higher relative returns to labour and land in crops than livestock), policies (e.g. land privatization, support for export crops), and changing quality of and access to services and infrastructure (Olson, 2006; Mwangi, 2007).

When pastoral households lose both their livestock and land, there is no way back, unless they are able not only to rebuild their herds, but also to raise the capital required to buy land. The decline of the communal pasture resources in Maasai land means that few numbers of livestock and an increase in the number those abandoning this age-old practice. In recent years, droughts have become more severe and frequent and are progressively eroding livelihoods in pastoral zones (Homewood et al., 2006). Therefore, pastoralists are forced to explore other livelihood options away from livestock to survive. However, diversification to on-farm options such as land cultivation constrain the carrying capacity of ecological niches to sustain long-standing ecosystem services and pastoral livelihood (Okoti, Kung, & Obando, 2017; Brown et al., 2006).

Among the Maasai, livestock production contributes to the sustainable livelihoods and security of the rural poor in many ways. It provides for natural capital (meat, milk, hide, rangeland, and pasture), source of financial capital (cash, saving, credit, insurance, gifts, and remittance) and social capital (Traditions, wealth, prestige, identity, respect, friendship, marriage dowry, festivity) (Yanda and Williams (2010). Land use change taking place in ASALs deny pastoralists access to vital pasture resources. In addition, drought lowers the amount of forage and reduces pastureland leading to land degradation, which cumulatively adversely affect livestock production. Despite these devastating effects, households in drought-prone ecological settings are expected to deploy assets at their disposal to meet their livelihood needs, primarily to achieve a reasonably stress-free life in the long run (Schmidt and Pearson, 2016). This conundrum suggests the need to identify the livelihood diversification options with promising prospects for driving communities towards drought resilience and to be the centres of action on enhancing adaptation capacity. Against this background, the study sets out to explore the nature of livelihood diversification in Kajiado County with special reference to the Oltiasika area and its effect on household food resilience to drought.

1.2 Problem Statement

Oltisiaka area that straddles the Chyulu-Amboseli ecosystem is a drought hotspot. Just like most parts of Kajiado County, pastoralism for years remained the most important livelihood activity in Oltiasika. The Chyulu-Amboseli ecosystem has experienced major land use changes in the past 30 years and recurrent drought and occupation of riparian zones by cultivators, who threaten access to water for domestic, agriculture, livestock and wildlife (Campbell *et al.*, 2003). As a result, livestock production and productivity has declined as grazing areas are gradually converted to other land uses (Morara et al., 2014; Olson et al., 2004). In the past three decades, the ecosystem has experienced major changes (Kioko and Okello, 2010) driven by human and natural factors. Wetlands which acted as dry season refuge have rapidly decreased due to conversion to farms, while changes in land tenure has affected land-use and vegetation cover (Msoffe et al., 2011; Nyamasyo and Kihima, 2014). Furthermore, formation of Tsavo, Amboseli and Chyulu National Parks denied the pastoralists a critical dry grazing area, exposing them to drought risks (Campbell et al. 2005). Land fragmentation weaken pastoralists as livestock movements is constrained and critical resource areas set aside for non-livestock uses (Sarah et al., 2016). The social and biophysical changes taking place drylands have attracted the attention of a number of scholars among them Kabubo-Mariara (2018), Roncoli, Okoba, Gathaara, Ngugi, and Nganga (2010), and Bryan et al. (2013) who have focused on adaptation strategies to climate change. These studies conclude that pastoralist are generally aware of climate change and have devised adaptation strategies. However, many of them assume that climatic extremes and drought is the primary driver of pastoralists to adapt, ignoring the effect of land use changes and human settlements. Specifically, there is dearth of studies that have examine the effect of livelihood diversification on household food security. This study therefore sought to shade light on the effect of livelihood diversification on household food availability to inform planning of pastoralism in dryland areas.

1.3 Research Questions

The study sought to address the following research questions:

i. What relationship exists between vegetation greenness and drought in Oltiasika area?
ii. In what ways have biophysical changes taking place in Oltiasika area affected pastoralism?
iii. To what extent does livelihood diversification influence household resilience to drought in Oltiasika area?

1.4 Objectives of the Study

The overall objective of this study was to investigate the role of livelihood diversification on pastoral household resilience to drought in Oltiasika area of Chyulu-Amboseli ecosystem of Kajiado County.

The specific objectives of this study were to:

i. Analyse the relationship between vegetation greenness and drought in Oltiasika area.
ii. Assess the effect of biophysical changes on pastoralism in Oltiasika area.
iii. Examine the effect of livelihood diversification on household resilience to drought in the Oltiasika area.

1.5 Study Hypothesis

The following hypothesis was tested in this study in objective three.

H_0: The resilience of households to drought in Oltiasika area is not influenced by the degree of livelihood diversification.

H_1: The resilience of households to drought in Oltiasika area is influenced by the degree of livelihood diversification.

1.6 Significance and Anticipated Output

Rising incidences of drought in Kenya is a concern not only to the national and county governments, but also to local communities who bear the greatest cost of the hazard. For this reason, the findings of this study are important for both policy development and planning for droughts adaptation and management. On the theory-practice front, the findings are a useful source of empirical insights that contribute to the understanding of the nexus between household resilience to drought and livelihood diversification strategies, particularly in the ASALs that are generally vulnerable to environmental stresses.

By moving beyond this conceptual boundary towards an integrated approach to analysis, the findings of this study constitute an important contribution to the body of literature on the dynamics of drought adaptation capacity in pastoral ecosystems. Insights from these field-based facts can, in turn, constitute crucial building blocks for socio-ecological theories on droughts adaptation.

From a policy perspective, the findings inform the design, planning, implementation and management of interventions on emerging livelihood strategies in the ASAL ecological systems, especially its relation to drought adaptation options. Additionally, the County Government of Kajiado will find the results beneficial for reviewing and strengthening strategies for fostering the economic and ecological well-being in its area of jurisdiction in the wake of climate change challenges.

1.7 Scope and Limitation of the Study

The study was conducted in Oltiasika area of Kajiado County in a stretch of land between the Chyulu Hills and Lake Amboseli. The area falls within a group ranch with pastoralism being the dominant livelihood. Although a number of livelihoods have emerged in the recent years, the focus of the study was on on-farming non-livestock activity.

Another limitation related absence of a weather station within the study area to provide rainfall data for computation of drought index. Upon consultations with the Kenya Meteorological Department (KMD), the study area falls within dry agro-climatic zones. Thus, rainfall data for the areas was inferred from the nearest weather station located in the same agro-climatic zone. This was considered adequate for assessment of drought trends and patterns.

Spatial temporal data used in the detection of land use changes in the area was obtained from google earth. Although this gives a high resolution, detection of cultivated farms and settlement patterns for the whole study area was not possible. Further, only a few years had images a factor that limited analysis of trends. Accordingly, change detection were shown for the 2011, 2012, 2014 and 2016.

1.8 Operational Definition of Key Terms and Concepts

Biophysical system: Natural resources mainly and vegetation which are used to support livelihood and are subject to degradation or decline.

Drought: The study adopts the definition of drought as a deficiency of precipitation over an extended period of time, usually a season or more, which results in a water shortage for some activity, group, or environmental sectors.

Food security: Ability to secure access to sufficient food for all household members throughout the year.

Household*:* In the "Maa" community, a household is a dwelling (Olmarei or Ilmareita in plural) with a head and his or her dependents. In case of a man headed Olmarei, it includes more than one wife, children, grandchildren, parents and other dependent siblings. A group of Olmarei comprises a homestead (Enkang or Inkang'itie).

Livelihood Diversification: A process whereby pastoralists pursue new and diverse activities in order to survive and to improve their standards of living.

Livelihood*:* A livelihood comprises the capabilities, assets and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base.

Pastoral systems: Refers to any economic and social system well adapted to dryland conditions and characterized by a complex set of practices and knowledge that has permitted the maintenance of a sustainable equilibrium among pastures, livestock and people.

Pastoralists: People who derive more than half of their income from livestock and related products.

Resilience: Is the capacity of households to cope with, adapt to and recover and learn from drought in a manner that reduces vulnerability to food insecurity.

Socio-Ecological System: Social-ecological systems are complex, integrated systems in which humans are part of nature.

1.9 Organization of the Thesis

Having presented the background to the study, described its conceptual scope and defined the key operational terms in Chapter One, the rest of the thesis is organized as follows: Chapter Two reviews the literature pertaining to the study topic, including the theoretical and the conceptual frameworks, Chapter Three details the research methodology employed, including ethical considerations, Chapter Four presents the empirical findings of the study. The summary of findings, conclusions, recommendations and areas for further research are outlined in Chapter Five.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of the literature related to the topic of the study, and describes the theoretical background upon which the study is premised as well as its conceptual framework. It is divided into three broad sections. The first section sets the scene by discussing key concepts and approaches to analysis of adaptation strategies to stressful environmental circumstances with special reference to drought, and the embedded search for resilience as the goal of struggle for sustainability within which the utility of livelihood diversification as a socio-economic and ecological philosophy is to be evaluated.

The second section describes the types of livelihood diversification approaches that have been established as common among native pastoral communities. This is followed by a synthesis of empirical scenarios and theoretical postulates that have been advanced in relation to the range of social, economic and ecological contexts that promote or inhibit the success of these diversification strategies as the hallmarks of resilience to stressful and shocking environmental encounters, with a focus on drought.

The province of literature used is drawn from diverse spatial settings, though those particularly on the wider Horn of Africa, Kenya and Kajiado County contexts are also highlighted. In the last part of section two, the policy and institutional environment for planning and implementation of household adaptation and resilience to drought in Kenya with a focus on livelihood diversification strategies is reviewed. Finally, the third section presents an elaboration of theoretical perspectives on livelihood diversification and household resilience to drought. The insights obtained from these theoretical perspectives are used as foundations of the resultant conceptual framework.

2.2 Understanding Drought

2.2.1 Drought measurement and its Impacts on Pastoralism

The idea of drought as a form of natural hazards and the set of livelihood diversification responses it evokes in the search for resilience has been an important subject for research and writing for several decades (Moritz, 2015). There exist different perspectives on drought and methods of measurement. The crux of this section is to interrogate these frontiers of knowledge in the field of planning and management of environmental hazards adaptation. Combating drought require a good understanding of its occurrence and characteristics through use of indices, a single number assimilating a large amount of data.

Drought can be categories into four namely; meteorological, hydrological, agricultural and socio-economic droughts depending on the value emphasis of the person concerned. Meteorological drought analysis consider drought as precipitation deficit with respect to average values. Hydrological drought is a period of below normal stream flow and depleted reservoir storage during which flow is inadequate to supply established uses under a given system, often persisting long after a meteorological drought has ended. Agricultural drought links various characteristics of meteorological (or hydrological) drought to agricultural impacts, focusing on precipitation shortages, soil water deficits, reduced ground water or reservoir levels needed for irrigation, and so forth. A decline of soil moisture depends on several factors that are affected by meteorological and hydrological droughts together with differences between actual and potential evapotranspiration. Socio-economic drought occurs when the demand for socio-economic goods exceeds supply because of a weather-related shortfall in water supply (combination of meteorological and hydrological drought impacts) or human induced factors (from increased population and poor production from deficiency or poor technology) (Schuman, 2006; Ayoade, 2004). Irrespective of the drought category, its severity depends on factors such as duration, intensity, geographical extent, and on demand of human activities and vegetation on water supplies. Various categories of drought complicate assessment of its effects on ecosystems, communities and economies (Panu and Sharma, 2002). Generally, drought produces multiple impacts across the economic sectors and social systems. In most cases, these impacts spread beyond the immediate area experiencing the physical drought. Hence, understanding the interaction between social and biophysical processes is critical in reducing drought effects.

Drought indices, a single number assimilating a large amount of water supply data (Ji and Peters, 2003) enable communication of climate anomaly to different consumers. Broadly drought indices fall into two: (a) drought indices based on water balance calculation and (b) statistical drought indices based on time series analysis (Szinell et al., 1998; Wu et al., 2001; Morid et al., 2006; Shakya and Yamaguchi, 2010). The water balance methodology requires application of several climatic and physical variables at a given time and space. Some of these variables might be calculated using some time series analysis, but overall, their final goal is to determine the water deficit of the crop at a given time and space based on a distributed parameter model. Examples of these types of indices include the Palmer Drought Severity Index (PDSI) (Palmer, 1965), the Palmer Hydrological Drought Index (PHDI), the Palmer Z-Index, the Crop Moisture Index (CMI), the Surface Water Supply Index (SWSI) and the Reclamation Drought Index (RDI). Statistical indices are based on one or maximum two parameters, mostly rainfall and sometimes temperature deficiency/excess. Commonly indices in this category include the Percent Normal Drought Index, the Precipitation Decile Index and the Weighted Anomaly Standardized Precipitation, the China Z-Index (CZI) (Wu et al., 2001), the Standardized Precipitation Index (SPI) (Mckee et al., 1993), and the Standardized Precipitation Evapotranspiration Index (SPEI) (Vicente-Serrano et al., 2010). These indices tend to be specific to regions and have the limitation of use under different climatic conditions, PDSI is extensively used in the United States), CZI in China and SPI in various regions. Notwithstanding these indices, studies on drought are hampered by difficulties in determining its onset and cessation and by the fact that the impacts creep slowly, can accumulate over a long period and may linger for years after cessation (Wilhite, 2000; Peduzzi *et al.,* 2010).

To date, SPI remain the most common index used to monitor drought. It is computed by first building a frequency distribution from time series of precipitation data of more than 30 years at a given location and time, with an interval greater than a month but less than 24 months (Wu *et al*., 2001; WMO, 2012). A gamma probability density function is then fit into the precipitation data and transformed into a normal distribution with mean zero and standard deviation one (Bordi and Sutera, 2007). SPI has advantages over other drought indices because of its relative ease and flexibility that allows observation of water deficits at different agro-climatic zones (Szalai and Szinell, 2000; Wu *et al*., 2001). In addition, users can choose the time scale most appropriate for computing the SPI (WMO, 2012). The index can also monitor dry and wet conditions over a wide spectrum of time from one to 72 months (WRCC, 2000). Based on an analysis of the drought in the Southern Plains and the South-Western United States in the spring of 1996 (Hayes *et al*., 1999) argued that the SPI is a more reliable index of developing drought conditions than the PDSI. This is because PDSI lacks the multiscale characteristics of droughts (Wang et al., 2015).

Assessing drought require rapid and continuous data that are usually not effectively collected by conventional methods. In particular, computation of SPI in drylands is hampered by poor distribution of climate stations, which limit availability of near-real time (Peters *et al*., 2002). This challenge is overcome by augmenting them with satellite images using Remote Sensing (RS) and Geographic Information System (GIS). RS and GIS techniques provide coverage of the whole area including remote areas on a regular basis that enable time series analysis (Anderson *et al*., 2010).

Ouma, Obando, & Koech, (2012) postulate that climate induced drought and climate variability are the root causes of the crisis facing pastoralists in Kenya. Drought results in loss of livestock and makes it hard for human-ecological systems to recovery after drought. During drought pastoralists incur huge losses with some losing more than half their livestock with average mortality rates of 50%, 30%, 24% and 17% for cattle, sheep, goats and camels herds respectively (Sanford and Habto, 2002). Such loses require long recovery periods and with recurrent droughts communities become more vulnerable as the herd growth is disrupted by ‘new’ droughts during the recovery phase.

2.2.2 Detecting Changes in Vegetation conditions by use of Vegetation Indices

Remote sensing, a technique that collects information by means of sensors operating in several spectral bands, mounted on aircraft or satellites, has emerged as an important technique in monitoring drought and in change detection across the world (Jain et al., 2009). Remotely sensed data is used to derive vegetation-based indices that reflect vegetation characteristics. Vegetation Index (VI) is used to assess drought and its impacts on phenology (Anderson *et al*., 2010). VI uses observations in multispectral bands, each of which give different information about surface conditions. Since drought is correlated with vegetation conditions, vegetation indices (VIs) are utilized for this purpose. VI is based on data in the visible red (R), near infrared (NIR), the shortwave infrared bands, and some in the thermal infrared (Karnieli *et al*., 2010). VI has many advantages over meteorological drought indices: the remote sensing data covers a whole territory and generate repetitive, spatial density of data is very high (1-km pixel resolution); the sensor covers large areas; and cover areas with low-density weather station (Kogan, 2002). The idea behind remote sensing is that green vegetation absorbs most of the visible light received from the sun but reflects a large proportion of the near infra-red light, while, dry vegetation reflects more visible light and less near infra-red (Frantzova, 2010).

Remotely Sensed Normalized Difference Vegetation Index (NDVI), developed by Rouse *et al*. (1974) and Tucker (1979) is widely used to detect vegetation change and vegetation phenology. NDVI is founded on the principle that green leaves absorb solar radiation in the photosynthetically active radiation spectral region as a source of energy for photosynthesis (Jensen, 2007). Thus, green leaves absorb solar radiation very strongly in the blue and red spectral regions and not as strongly in the green spectral region. In the near infrared spectral region, green leaves are highly reflective and no absorption occurs (Jensen, 2007). As a result, green leaves have high visible light absorption plus a high near-infrared reflectance, leading to high NDVI values. Water has negative NDVI values, while clouds, bare ground, concreate and snow have NDVI values close to zero (Neigh, Tucker, and Townshend, 2008).

NDVI is a slope-based assessment technique that separates the green vegetation from its background soil brightness and is expressed as the difference between the maximum absorption of radiation in R resulting from chlorophyll pigments and the maximum reflectance in NIR spectral region resulting from leaf cellular structure normalised by the sum of those bands (Karnieli *et al*., 2010). Mathematical the index is derived as:

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} - \rho_{RED}}$$

Where: $\rho_{NIR}$and ρ_{RED}, represents spectral reflectance in the NIR infrared channel and red-channel respectively of the satellite sensor, where the vegetation has a high reflectance in NIR, and low reflectance in red visible colour channel. NDVI is dimensionless with values ranging from -1 to +1 to correspond to non-vegetated and forest surfaces respectively (Justice *et al*., 2002).

Studies have shown that NDVI is highly correlated with photosynthetically active radiation absorbed by the plant canopy, photosynthetic capacity, net primary production, leaf area index (LAI), fraction of absorbed photosynthetically active radiation, carbon assimilation and evapotranspiration (Buer-mann et al., 2002, Hicke et al., 2002, Wang et al., 2005). Because of these properties, NDVI is used to monitor vegetation healthy through time and enables easy temporal and spatial comparisons and to map, assess or predict the occurrence of disturbances such as drought, fire, flood and frost and land degradation (Pettorelli et al., 2005; Prince, Becker-Reshef, and Rishmawi, 2009). Though commonly used in densely vegetated areas, NDVI could provide useful information even in sparsely vegetated areas as is the case in arid and semi-arid lands (Santin-Janin et al., 2009). In particular, satellite-derived Normalized Difference Vegetation Index (NDVI) images have been widely used to identify poor pasture conditions (FEWS, 2000.)

The stability of NDVI allows comparisons of seasonal, inter-annual, and long-term variations of vegetation structure, phenology, and biophysical parameters (Tucker and Sellers, 1986). This permits correlation between NDVI and level of vegetation stress.

In addition, it is possible to evaluate the lag effect by comparing NDVI values and rainfall data (Schmidt and Karnieli, 2000).

Anyamba and Tucker, (2005) computed NDVI using data obtained from NOAA-AVHRR from the period 1981-2003 and 1930-1965 to analyse vegetation dynamics in Sahelian. The results show some periods marked by below average NDVI over the long-term mean. In the Kalahari Transect Savannah ecosystems were found to be sensitive to rainfall on short time scales (Scanlon and Cook, 2002), while in Eastern Africa region a positive relationship was established between rainfall deficit and vegetation stress (Musaningabe, 2012). Lewis *et al.* (2010) have computed NDVI to monitor yields in maize production in Kenya.

Thomas *et al*. (2004) provide a useful criticism of use of the NDVI. They argue that generally NDVI is affected by other variables that limit its capability in estimating vegetation water condition. Further, a decrease in chlorophyll content does not imply a decrease in vegetation water conditions, and a decrease in vegetation water condition does not imply a decrease in chlorophyll content. Further, different flora has its own relationship of chlorophyll content and vegetation water condition, while a time lag between vegetation responses to rainfall deficit of about one month has been observed (Peters *et al*., 2002). The use of NDVI is further constrained by the fact that during extended period of cloud coverage, its value tends to be depressed giving a false impression (Tsegaye, 1998). In addition, the Index gets saturation when used in closed canopies and is sensitive to atmospheric aerosols and soil background (Wang *et al*., 2003).

Chantarat et al. (2013) have used NDVI to design livestock insurance scheme for Kenya's ASALs due to lack of reliable station rainfall data. NDVI is used as a proxy for forage availability which determines the condition of livestock conditions in a pastoral production system. They rely on MODIS data source to generate NDVI but note that since MODIS covers only the years from 2000 it is insufficient to capture the full range of climatic variability and the related drought probability.

The Temperature Condition Index (TCI) and Vegetation Condition Index (VCI) are other indices used to monitor vegetation changes. VCI was first suggested by Kogan (1995) to show degree of closeness of monthly NDVI to long-term minimum NDVI monitor drought using AVHRR data. It is the difference between the current NDVI and the minimum NDVI for the entire record normalized by the range. The Enhanced Vegetation Index (EVI) minimizes soil and atmospheric sensitivity in NDVI by including the blue band for atmospheric correction (Huete *et al*., 2002). Mahyou *et al*. (2010) employed a Vegetation Condition Index (VCI) based on Landsat imagery to investigate the impact of drought based on eight-year time series.

The Normalized Difference Water Vegetation Index (NDWI) was developed to monitor drought. NDWI is sensitive to changes in water content in vegetation and combines the near-infrared and short-wave infrared bands to estimate vegetation liquid water. Horion *et al*. (2010) used 10-daily SPOT-VEGETATION images for the period April 1998 to October 2003 to monitor summer drought in Belgium. The results show that historical values of the NDWI are useful to detect, delineate and monitor drought-impacted areas.

From this overview, several indices exist to encapsulate drought and a choice of indices depends on the purpose for which the assessment is being undertaken. As a general a rule of thumb, drought index is useful if it provides a clear, simple and quantitative assessment of the major drought characteristics: intensity, duration and spatial extent (Hayes *et al*., 2000). In the East African region, a study by Ntale and Gan (2003) concluded that precipitation alone explains much of the variability in meteorological drought. Thus, SPI is a more appropriate measure of drought because of its adaptability to the local climate, is less data intensive, captures any time scale, produces more consistent spectral patterns across the region, has no theoretical upper or lower bounds, and is easy to interpret.

2.3 Land use changes in pastoral rangelands

2.3.1 Group Ranches and Livelihood systems in Kajiado County

In the late-1880s and early-1900s, the attitude of the British towards pastoralists was to sedentarize them, in an effort to politically pacify and maintain law and order. The Crown Lands Ordinances of 1901 and 1902 declared all land in Kenya be “Crown Land” belonging to the Queen of the United Kingdom, and authorized the High Commissioner to Kenya to evict Africans from their traditional lands to be confined to “native reserves”. The land was allocated to white settlers for commercial production. Later pastoralists lost more land through the creation of protected areas for wildlife conservation (Viet, 2011).

The Swynnerton Plan of 1954 was adopted to address African land problems by reforming land tenure, consolidating fragmented holdings, issuing freehold title, intensifying and developing African agriculture, providing access to credit, and removing restrictions on growing crops for export (Bradshaw 1990). The plan consisted of a three-phase programme: (1) land adjudication to "phase out" customary tenure; (2) land consolidation into one block per household to eliminate small, dispersed parcels, to allow greater specialization, and to realize economies of scale in production; and (3) land registration to provide for security of ownership and to establish a land market. This aimed to facilitate increased investment and employment in agriculture and to increase rural incomes and the "productivity" of land (Okoth-Ogendo 1976, 1991; Wangari 1991). It was predicated on an assumption that "successful" or wealthy African farmers would "be able to acquire more land and bad or poor farmers less, creating a landed and a landless class" (Swynnerton 1955, 10, cited in Wangari 1991). As a result, many grazing schemes, each with a livestock officer-in-charge, were started in various parts of the country.

The livestock officers were responsibility for running the schemes as "models" in livestock management and range resources utilisation. The idea was meant to convince the pastoralists to reduce their livestock numbers to avoid overgrazing, to reduce erosion and to realise reasonable annual off-takes. Most pastoral groups were suspicion and believed that the colonial government did not understand the real nature of pastoral cultures and therefore were noncommittal to the success of grazing schemes. They preferred short-term benefits and moved out of the schemes during periods of hardships.

After independence, the Government of Kenya submitted a proposal for a livestock project to the World Bank that proposed a variety of organizational structures for the different social and ecological systems in the country. For the better-watered pastoral areas this entailed shifting the production from subsistence to commercial through group ranching. The United Nations Development Programme (UNDP) and the Food and Agriculture Organization agreed to support the plan by undertake an inventory of the range resources, livestock and wildlife populations and hydrology as a basis for more detailed planning. The concept of a group ranch was for the first time articulated in the Lawrence (1966) Mission Report which advised that land registration in pastoral areas should be on a group rather than on an individual basis (Bekure, de Leeuw, Grandin, and Neat, 1991). The rationale was that under individual ranch regime, chronic land shortage would be created affecting many people who would not be able to acquire individual grants. The government encouraged the establishment of group ranches in the hope of supporting the small livestock owners who would not afford the necessary ranch inputs such as dips and the required water infrastructure to maintain a viable ranching unit. Group ranches were perceived to reduce the cost of inputs and thereby improve their viability.

The Lawrence report produced the legal framework of the group ranch and was later enacted as the group representative Act of 1968 (GoK, 1968). The Act defined a group ranch as a livestock production system or enterprise where a group of people jointly own freehold title to land, maintain agreed stocking levels and herd their livestock collectively which they own individually. The act legalized ownership and occupation of land by a group of people and enabled participants to acquire funds for development and operation from local financial institutions. The resultant development created projects in two broad types of production systems namely commercial production systems in the form of a company, co-operative or individual ranches and pastoral production systems in the form of group ranches and grazing blocks. The groupings were dependent on land tenure and social organisations (Ayuko, 1981).

The Maasai embraced the group ranch practice for the four main reasons. The group ranch practice offered the possibility of increasing their traditional wealth base, i.e. livestock numbers through provision of water facilities, disease control and through acquisition of more animals as provided in the group ranch plans. They also offered the certainty of maintaining land under Maasai people since non-Maasai could not be members of any group ranch and land sales could not be possible as land was adjudicated to a group. Further, the group ranch practice seemed to offer social and cultural stability, and finally this was to provide the medium of transferring state land from government hands to the Maasai people. This would initially be through freehold communal land tenure system which is the group ranch and ultimately to individual freehold ownership by subdivision of the group ranches to individual members (Grandin, 1991).

The Maasai communities were formally settled in Oltiasika after independence in 1963 during the formation of group ranches in Kajiado County. Most of the people moved into this area from Loitoktok and own other land parcels there. Mbirikani group ranch is managed as an open access resource and members are not restricted on the number of animals to keep. An executive committee elected by members, the first of which was elected in 1970, manages the group. In the past two decades, the area has experienced migration particularly from other communities mainly driven by search for arable land. Scholars such (Kibugi, 2009; Mwangi, 2007) as have questioned the viability of ranches amid growing land subdivision and climate change.

2.3.2 Land use changes in rangelands

In Africa, rangelands cover nearly half of the total land mass and support pastoralism, characterized by herd mobility to track grazing water resources in space and time (Nkedianye et al., 2011; Tefera, 2014; Berhanu and Beyene, 2015). However, land use changes in these areas has attracted major global concern to conservationists and researchers alike (Msoffe et al. 2011). A large body of work has examined land use changes taking place in dryland area. Campbell el al., (2000) used geographic information systems (GIS) to assess changes in Kajiado County. The results show that the County had experienced rapid and extensive land use and land cover in the past three decades due to economic, cultural, political, institutional, and demographic processes. Household surveys have also been carried out to examine household variables that drive land use changes (Rindfuss et al., 2003).

Sedentism by formerly mobile African pastoralists has been found as one of the key drivers of land use changes in rangelands. This practice is mainly due to economic, political, demographic, and environmental transformations taking place in these areas. These changes have affected the traditional livelihood. Although majority of pastoralist households in Kenya's Savanna are still engaged in livestock, many formerly pastoral families are now involved in other activities including cultivation, agro-pastoralism, and urban wage labor (Fratkin, Roth, & Nathan, 2004).

A study by Said et al. (2016) examined the factors driving land fragmentation in Athi-Kaputiei Plains of Kajiado County. Their findings show that human settlements were concentrated in areas with high biological value. As more people encroach into this pastoral land, they fence off the grazing areas and block the migratory paths for both wildlife and livestock. With the aid of GIS techniques, they were able to detect land use changes in the Athi-Kaputiei Plains in the last three decades. The changes were mainly attributed to changing policy and legislation on land use, access and tenure arrangements, historical alienation of Maasai land, proximity to Nairobi city, infrastructure developments and relatively low prices of land.

A comprehensive review of literature by López-i-Gelatsa (2016) using cluster analysis concluded that land use changes is driving vulnerability of pastoralists to climate change. Their finding revealed that pastoral lands in Eastern Africa were being transformed by emergence of non-pastoral activities leading to declining pasture and water resources for the livestock and political marginalization of the pastoralists. Declining natural resources exposed the pastoralist to drought risks. The main causes of transformation of pastoral areas are were failure in land-use policies which did not recognize land rights of the pastoralist, sedentarization schemes and extension services that were often designed and implemented in ways that marginalize pastoral livelihoods, while prioritizing other enterprises such as agriculture, infrastructures, urban areas, ranching, tourism or mining.

Demographic changes characterized by population growth and immigration of traditionally farming communities are other factors influencing land use change in Kenya (Goldman and Riosmena, 2013). To adapt to declining natural resources, pastoral households respond by enhanced mobility, diversification and communal pooling, as well as market integration. During drought they moved to areas rich in pasture and changde grazing patterns while wage labor, migration and remittances become critical survival strategies. Although both Said et al. (2016) and López-i-Gelatsa (2016) acknowledges emigration into pastoral areas, they ignore its role in the growing non-pastoral livelihood activities.

Land use changes has affected livelihood and food security of pastoralists. A study by Haji and Legesse (2017) investigated the factors responsible for sedentarization and its effect on livelihood and security in Ethiopia using the propensity score matching method. The study used a sample size of 213 households to compare food availability among sendentarization and non-sendentary pastoralists. The findings showed that sedentarization was significantly and positively influenced by education distance to road and extension services, but negatively affected by household size and number of livestock owned. Sedentary households had higher expenditures on education and more sources of income, but resulted in significantly decreases in percentage expenditure on food. Although pastoral sedentarization was found to improve the livelihood of households, it worsened their food security in the long term.

2.4 Livelihood Diversification and Household Resilience

2.4.1 Dimensions of Livelihood Diversification

A livelihood strategy entails not only activities that generate income, but also other kinds of choices, including cultural and social choices, that combine to make up the primary occupation of a household (Ellis, 1998). Livelihood diversification is defined as the "process through which rural households construct an increasingly diverse portfolio of activities and assets to survive and to improve their standards of living" (Ellis, 2000). Diversification is meant to expand the scope of income sources available to a household to enhance their adaptation capacity or survival in the wake of natural hazards such as drought.

Niehof (2004) provides an important definition of the concept of household diversification in relation to attainment of resilience to drought; the process by which households construct diverse livelihood portfolios by making use of increasingly diverse combinations of resources and assets. Households diversify to spreading risk, consumption smoothing, labour allocation smoothing, address market failures, and to cope with shocks. Prompted by survival or the need to improve their standard of living, households construct a diverse portfolio of activities and social support capabilities. They can combine many livelihood activities like agricultural crop production, livestock production, wage work, cottage industry to r supplement income. The mix of activities will depend on a household's ability to access different livelihood opportunities (Bryceson, 2002).

Depending on the ecosystem of focus, the nature of environmental stress one is focusing on, the concept of livelihoods diversification elicits different perspectives. These differences also come about depending on the spatial context or economic context one is talking about (Turner *et al*., 2003). Irrespective of these different perspectives, the forms and characters of livelihood diversification and the factors that militate against or promote them are common. They run the gamut of charcoal production and firewood collection, and increase production of handicrafts and accelerated restocking (GoK, 2007a).

From the perspective of livelihood sustainability, households deploy a combination of assets to maximize benefits associated with changes in living standards and with prospects for minimal reduction of the risks of food insecurity and long-term livelihood security (Care International, 2015). In addition, declining returns in certain livelihood activities and the need to strengthen coping capacity to shocks or risk minimization drives the livelihood diversification process (Barret *et al*., 2000).

Pastoralism has historically been an important economic activity in Kenya, particularly in the ASALs, where 80% of the population depends on it (NEMA, 2008). It is a specialized form of natural resource management characterized by limited, variable and unpredictable agro-ecological resource endowment. To make optimal use of dry land ecosystem, pastoralists practise a mobile, extensive livestock rearing system and use different herd management strategies such as hard splitting, herd diversification and herd maximization to spread the risk of livestock loss due to droughts, diseases, theft and hazards without degrading the natural environment (Yimer, 2015).

This type of livelihood developed out of the need to constantly adapt to the extreme climate uncertainty and marginal landscapes of the dry lands. In recent years, due to the problems of drought coupled with population pressure, and the spread of pest and diseases, creating alternative livelihoods is one of the current critical environmental challenges facing the customarily pastoral communities in a country. The problem of land use conflicts in these ecological systems has been exacerbated by the expansion of modern sector enterprises such as irrigation; ranches and game parks, and increasing population, which is less likely to be supported singly by relying on the dwindling herds of cattle (GoK, 2007b).

Drought management remains an important issue for environmental planning and management in the Kajiado County ecosystems as they result in loss of livestock and hunger among inhabitants (GoK, 2007b). These problems are exacerbated by the increase in the number of female-headed households, rising poverty levels, reduction in environment quality, and increased pressure on the natural resources.

Instead of addressing this marginalization and reinforcing capacities for adaptation, both state and non-state actors' interventions have tended to focus on provision of emergency assistance, and these have further undermined sustainable development of affected communities because they have been either late or not approximately tailored to the circumstances of the needy population and the environment (Dupnis & Knoepfel, 2013).

Traditionally, pastoralism was the main livelihood among Maasai, with raw blood, milk, fat, honey, meat and tree bark comprising the main diet (Chege, Kimiywe, & Ndungu, 2015). However, recurrent and extreme weather events and changes in markets, land tenure, population and urban growth have greatly affected these production systems (BurnSilver et al. 2008; Hobbs et al. 2008). The traditional systems are slowly changing although a significant number continued with the age-old customs. In particular, with recurrent drought, market-based livelihood has become more important and pastoral communities are experiencing a transition from subsistence production to increasing dependence on market-driven goods and services including purchased foods, clothing, household articles, health care, and veterinary services(Galvin, Beeton, Boone, & Burnsilver, 2015).

2.3.2 Perspectives on Livelihood Diversification and Adaptation

The essence of livelihood diversification is either to cope or adapt to unexpected changes. Coping deals with short-term insufficiency of income to meet household needs, while adaptive is a long-term measure, which meets up family needs through non-farm enterprises. Diversified households tend to have diverse activities with similar shares of income, while less diversified ones have either small number of activities or many activities but with only a few which accounts for high income shares. The level of household diversification is measured using indices, although there are differences on the conception of livelihood diversification (Mehta, 2009).

Experience has shown that households mostly derive their income from multiple sources and tend to hold assets in more than one form (Ellis, 2000). There are various reasons why households diversify their activities, income and assets, key among them: (i) to increase income for the household when income from the main activity is limited, (ii) to reduce income risks, (iii) to exploit strategic complementarities and synergies between different activities and (iv) to realize economies of scope where the same inputs generate greater per unit profit when spread across multiple outputs (Babatunde and Qaim, 2010; Minot *et al*., 2006).

The decision by a household to diversify is determined by various factors that can generally be classified into two categories: push and pull factors. The main push factors include the need to reduce risks and smooth consumption (Barrett *et al*., 2001). Diversification is used as a risk management strategy due to lack of social safety nets among many African households. De Janvry *et al.* (2006) also argued that because of deficient rural credit and insurance markets in China, participation in nonfarm activities is the best alternative, as income from nonfarm activities could be used to increase investment in farm activities, mitigate income fluctuations and play the role of an insurance system. Bryceson (2002) argues that many African households were driven into economic diversification by the implementation of structural adjustment programs in the 1980s in a bid to minimize risk. Because of uncertain climatic conditions, rural farmers ventured into crop diversification to minimize risks.

Various socio-economic factors determine the choice of livelihood strategies. Minot *et al*. (2006) found a positive and significant relationship between education of the household head and the degree of diversification. This is because education could enhance the chances of engaging in different activities through, for instance, participation in wage employment and facilitating learning of new opportunities. The size and composition of the household also matter. Larger households with fewer dependants (children and elderly) tend to have more income sources as compared to smaller households. This is mainly due to the declining marginal productivity of additional farm labour as the household size increases, which makes venturing into alternative sources of income more attractive. Further, larger households are expected to have a diversified portfolio of skills and knowledge, which would allow the diversity of income sources at the household level (Minot *et al.*, 2006).

The amount of labour within a household is also a strong factor in pushing households towards nonfarm activities, especially wage employment and non-agricultural self-employment (Winters *et al*., 2009). This is because rural households with greater labour endowments are likely to have higher labour-to-land ratios. Further, more labour is also associated with greater income gains from the nonfarm activities. Availability of key factors of production, such as land, can be a key push factor for households to diversify. Research evidence (Minot *et al*., 2006; Winters *et al*., 2009) has shown that land availability is a key determinant of income diversification.

Households with more farm size tend to have a larger number of crops with more marketed surplus, but with less non-farm income and income diversity. Lanjouw *et al*. (2001) showed that larger household per capita landholdings reduced the probability of an individual engaging in the business sub-sector, which implies that large landowners were more likely to engage in agricultural activities than small landowners. However, they found that very large landholdings were associated with a higher probability of engaging in business activities.

Lay and Schüler (2008) argued that both the total amount of land and land per adult equivalent should be considered while looking at the effects of land on diversification. In their view, total land is an important asset that allows the household to overcome entry barriers into both farm and nonfarm activities. On the other hand, farmland per adult equivalent measures the ability of the household to adequately provide land and food to its members. It is expected that the likelihood of diversifying into the nonfarm sector increase with the size of land; while in contrast, households are likely to be pushed into nonfarm diversification with less land per adult equivalent (FAO, 2015; Kassie *et al*., 2017).

Pull factors, on the other hand, are mainly associated with an increase in opportunities for diversification that are linked to: higher sources of income resulting from rural development, increased commercialization of agriculture, increased urbanization and better market access. Babatunde and Qaim (2010) argue that while poor households could pursue distress-push diversification, there seemed to be a significant element of demand-pull diversification (Barrett and Reardon, 2001), which, for instance, could result from: (i) increasing household income, which provides the means to overcome investment entry barriers and also generates an increased demand for nonfarm goods and services; (ii) shifting from traditional goods and services to commercially-oriented farming and non-farm activities as the rural economy develops, which stimulates diversification; and (iii) increased urbanization resulting from long-term population growth and density and infrastructural development, which could lead to the development of the nonfarm sector, thereby promoting diversification. Dercon and Krishnan (1996) also argue that differences in household portfolios can also be explained by access to public infrastructure such as marketplaces and roads and proximity to towns and common property resources.

There exists empirical evidence showing that diversification leads to higher household income and reduces the likelihood of being poor. Freeman, Ellis and Allison (2004) used data from rural Kenya to show that households that relied heavily on agriculture were poorer than those that combined food crop agriculture with livestock keeping and engagement in non-farm activities. They provided evidence that rural poverty reduction efforts require a broader focus that encourages and facilitates' diversity and mobility.

A study in Malawi found that securing a better living standard for rural households requires an ability to accumulate assets and to diversify sources of income into both farm and nonfarm activities (Ellis and Freeman, 2005). They argue that rural poverty in Malawi can only be tackled through a combination of raising agricultural productivity, diversifying farm output to reduce risk, shifting towards higher value crops and diversifying into nonfarm activities. Engagement in a diversified livelihood portfolio has been found to reduce the risk of being poor among Nigerian households (Awotide *et al*., 2010), while rural households in Zambia who participated in nonfarm activities had a higher level of income as compared to those who participated in farming alone (Bigsten and Tengstam, 2008). Other studies (e.g., Ellis and Bahiigwa, 2003 and Ellis and Mdoe, 2003) lend support to the argument that less reliance on agriculture is important for poverty reduction and that those households that rely on more diversified sources of livelihood are less likely to be poor.

While poor households in rural Kenya rely only on subsistence farming as a single source of income, richer households relied on multiple sources of income; including farming, wage income and nonfarm activities. A study in Kitengela, Kajiado by Radeny, Nkedianye, & Kristjanson, (2007) found that an overwhelming 85 per cent of households earning came from non-livestock sources point to high degree of diversification. According to Start (2001), livelihood diversification has two related components: *multiplicity* where the livelihood activities are concurrent and transformation; or *adaptation,* which involves changes from an essentially subsistence agricultural sector to non-subsistence, non- agricultural sectors. Among pastoral communities, livelihood diversification is a pursuit of non-pastoral income generating activities meant to meet the consumption needs of households and buttress against climate related shocks, animal losses market losses, and insecurity (Little, 2001).

At the centre of livelihood diversification and household resilience to drought is a range of benefits of the ecosystem effect. Scholars like Turner *et al*. (2003) have posited that native people intentionally change the temporal and spatial characteristics of ecological cycles to create physical edges, thereby increasing the abundance of resources at their disposal to survive. These diverse ecological resources, thus, not only redefine but also elevate their livelihood structures in response to emerging changes in their locales as evidence from parts of North America. As numerous studies cited in Turner *et al*. (2003) have shown, edge-producing practices are widespread tools for anchoring self-sufficiency and maintaining and livelihood flexibility as a means to remain economically stable and ecologically resilient in the wake of unexpected deprivations in the ecological systems.

Some of the advantages these ecological interfaces provide, also referred to as ecosystem effects, are access to water for domestic and pasture use, transportation and accessibility to a wider range of resources at various spatial scales than if they were situated only within one ecosystem. In addition, ecosystems facilitate the exploitation of resources from the two major ecosystems (Turner *et al*., 2003). Ecosystems are likely to be transient and related to a stage of ecological transition in the wake of disturbances or alternations in the traditional ecological conditions, thereby necessitating the emergence of new socio-economic regimes. Such diversification of activities can be either long-term or temporary and can include a new set of activities.

Sustainable diversification entails a process of people adopting new technologies, knowledge and skills, supported and organized through social and cultural institutions. By taking advantage of the supportive and organizing principles embedded in their social and cultural settings, communities make use of, create ecosystems on the landscape, simulate the ecosystem effects through social exchange, and interchange (Childs and Killick, 1993). Such processes are key in building community's resilience to drought.

In the Chyulu-Amboseli ecosystem, drought induced livelihood diversification present both social and ecological conditions and the interactions between these two frontiers over time and space (Campbell *et al*., 2003). The strategies to cope with food shortages are embedded within existing rural socio-ecological systems and may alter as the society undergo structural transformations due to exogenous and endogenous forces.

Berhanu *et al*. (2007) have studied livelihood diversification behaviour among the Borana pastoralist in Southern Ethiopia using a production function. The results suggest a shift to cultivation and other non-pastoral activities and established five categories of diversification. However, there were great disparities in household diversification portfolio along socio-economic characteristic of age, literacy, and exposure to the exchange system.

Under emergency, farmers have survived and coped in various ways over time (Nhemachena and Hassan, 2007). They employ diverse risk-mitigation strategies, including diversifying crops, mixing crop and livestock production, keeping multiple species of livestock, and joining rotating credit groups. Coping strategies at the household level include selling productive assets, selling livestock and agricultural products, reducing current investment and consumption; employing child labour, temporarily or permanently migrating, mortgaging land, and using inter-household transfers and loans (Deressa *et al*., 2010). Smucker and Wisner (2008) have noted that although drought affects communities, they devise various response strategies. However, not all strategies are compatible with the long-term agrarian livelihood requirements in terms of enhancing the resilience of the household to past and expected drought incidences.

The view of migration as a form of livelihood diversification has received attention in recent years with growing literature agreeing that migration is strongly linked to social networks, which in turn are crucial stepping-stones to housing, employment opportunities and support systems for the migrants (De Haan *et al*., 2002; Hampshire, 2002). Analysis of the implications of migration, expanding cultivation, and influencing political leadership among the Maasai pastoralists reveal that it is leaving a cultural norm, rather than a response to economic hardships (McCabe *et al*., 2014).

An illustration of this is Stakhanov's (2010) use of household data to evaluate the livelihood diversification in households with HIV positive and negative mothers in Ghana. Livelihood diversification was derived from a weighted composite diversification index, computed on three-four income activities of livestock, farming and work for wages and receiving remittances. In a study by Saha and Bahal (2010) in West Bengal in India employed the Simpson Index of Diversity to examine nature and extent of livelihood diversification among farmers. The findings revealed that families pursue a combination of activities for income stabilization and risk mitigation. These activities were a blend of mix-farm, off-farm and non-farm activities. Trading and artisanship were the most important activities in the area.

The Herfindahl Index (HI) is another measure commonly used to quantify the extent of livelihood diversification among rural households (Kimenju & Tschirley, 2009). The main advantage of HI is its ability to measure share of diversified activities in the total household economic activity or income.

Sedentary agriculture was identified as an important strategy although diversification into service provision is limited (Little, 2001). Majority of people were found to diversify for purposes of survival, while gender, distance to urban centres, and wealth status were key determinants of diversification. In addition, diversification is influenced by education, access to market and infrastructure (Liyama, 2006).

2.4.2 Livelihood Diversification and Household Coping Capacity

The effect of livelihood diversification on household capacity to cope to drought has attracted a number of scholars. While as some livelihood diversification strategies can increase pastoralists' resilience to external shocks, others can increase their vulnerability to these shocks (Pedersen and Benjamin-sen 2008; McCabe 2003). Farming, which is often the first alternative that traditional pastoralists pursue, has been utilized widely despite the inadequate environ-mental variables for rain-fed cultivation in these arid areas (Little et al. 2001). Other strategies include wage employment, subdivision of land, livestock trade, petty trade, home brewing and sale of alcohol, charcoal burning, tourism, and hunting among others. Cultivation is seen a first step towards cushioning households against deficits in animal production.

According to Kabubo-Mariara (2018) some livelihood strategies in drylands inflicts pressure on the resource capacity of ecosystems, thereby reducing their ability to remain stable in the event of natural hazards. Communities are thus more vulnerable when they diversify their livelihood compared to their initial conditions. In the light of this, drought resilience attained through livelihood diversification within an ecosystem needs to be viewed in terms of its contribution to food poverty (IPCC, 2012).

The second perspective rests on the view that most disasters are because of a complex mix of poor development, poor planning and low regard to environmental conservation. Thus, any, interventions in response to drought would succeed if facilitated in a manner that is responsive to the social and economic contexts of the beneficiaries and in ways that are environmentally sustainable (UNEP and CUAS, 2015). Finally, the third hypothesis holds that (natural) disasters are aggravated by climate change (IPCC, 2014).

When households experience uncertainty and the prospect of negative shocks, they diversify livelihood to cope with risk (Ellis and Freeman, 2005). This process entails expanding the portfolio of livelihood activities and assets to survive or improve living standards by switching from one livelihood strategy to another. Livelihood diversification does not always mitigate the negative effects of shocks. Livelihood diversification can be inferior to specialisation, while its motivation varies between the rich and poor households –the former for development and wealth accumulation and the later for survival (Carswell, 2000). Irrespective of the motivation, households willing to diversify will have to overcome constraints on capital or skills, norms, taboos and cultural values (Dercon, 2002; Arce, 2003).

While there is growing consensus that pastoral communities pursue many strategies to cope with drought (ILRI, 2005), few studies have quantified the effectiveness of these strategies on household income. According to Wangai *et al.* (2013), drought is a threat to social and environmental wellbeing and requires empirical evidence to aid in the formulation and development of resilience measures for the households. Thus, examining livelihood activities in relation to drought is an important step in determining plausible adaptation options upon which patterns and structures of planning and policy actions for sustainable future can be premised.

In Indonesia, Schwarze and Zeller (2005) applied a Shannon Equitability Index to examine the shifting from agricultural activities towards an increasingly mix of income activities. The Index was used to measure the overall household income diversification and considers both the number of income sources used by the household and their evenness. The results showed that poverty had a negative influence on the Shannon equitability index, meaning that the income of poor households tend to originate from many sources and is evenly distributed. However, social network had a significant and positive influence on diversification, as it enabled members to extend their scope of livelihood activities.

Bhatta and Aggarwal (2015) carried out a cross-country study of smallholders in Southern Asia to examine coping strategies under adverse weather conditions. Their study was based on data collected from a sample of 2660 and analysed using qualitative and quantitative techniques. The findings showed use of female labour, migration and expenditure smoothing were the three most adaptation employed by small-scale farmers.

In a study conducted among pastoralists in northern Kenya and southern Ethiopia, Little *et al*. (2001) conceptualized livelihood diversification as the pursuit of any non-pastoral income-earning activity; whether in rural or urban areas, including trading occupation, wage employment, retail shop, rental property, gathering and selling wild products and farming. Their research shows that pastoralists generated incomes from diverse streams, although pastoralism was still the primary income activity. Their findings show that human population exerted pressures on pastoral diversification by limiting land for communal grazing and increasing the need to intensify into non-pastoral activity. Households with diversified income sources were found to be better at coping with economic, political and ecological risks than those without. However, diversification does not automatically translate into improvements in incomes. The alternative activities may have even much lower prospects for presenting a stable income base, thus, compromising the chances of resilience to hazards for households.

Berhanu *et al*. (2005) analysed patterns and implications of livelihood diversification among Boran pastoralists in Southern Ethiopia using cross-sectional data from a sample of 150 households to identify adaptation strategies. They employed ranking technique to isolate key adaptation strategies, while Cobb-Douglas production model was employed to examine the shift from pastoral to non-pastoral activities. Berhanu *et al*. (2005) concluded that diversification through cultivation had a positive but statistically insignificant effect on household income. However, farming and pastoralism were found to be highly competitive in their use of the natural resource base of the system, therefore raising concerns about the long-term implications of expanding crop faming. The results further showed that farming does not necessary result in improved livelihood because of the low productivity of the semi-arid environment.

Not all response strategies have similar outcomes. In Vihiga and Embu counties of Kenya, a study to analyse the effect of different livelihood strategies among rural farmers revealed a statistically significant difference in various clusters of livelihood strategies. In addition, coping mechanisms were found to reflect a household's priorities and options during a crisis. Immediate economic or food deficiencies are often the priority, followed by maintenance of the means for long-term livelihood generation. Some coping mechanisms are thus geared toward minimizing short-term threats while others are oriented towards maintaining a long-term livelihood source (Brown *et al*., 2006). In an ecological setting, as resources dwindle, households decide on how the remaining resources of time, energy and finances are allocated optimally to meet the needs of the household. However, as the crisis worsens, more extreme and diverse coping methods are invoked. In an emergency, households will employ strategies that completely disregard long-term priorities, such as the sale of land by subsistence farmers (Eriksen et al., 2005).

Though coping strategies depend, in part, on household characteristics and priorities, they also depend on community dynamics. In some communities, for example, consumption of certain wild foods is so stigmatized that they will not be consumed unless a state of emergency exists, whereas in other communities the consumption of wild foods is a first line of defence to maintain food security (Smucker and Wisner, 2008).

Empirical measurement of household resilience has been popularized by the Food Agriculture Organization (FAO)'s Resilience Measurement Technical Working Group. According to the Technical Working Group, resilience can be measured over a given point of time and over an extended period and covers multiple constructs (Constas *et al*., 2014). The approach selected for resilience measurement depends on the data available and the purpose for the measurement but generally covers *ex-ante* and *ex-post* conditions of wellbeing and vulnerabilities, as well as the description of the disturbance.

Studies conducted in Kajiado County affirm that pastoralists are increasingly diversifying their livelihoods to reduce environmental risks and uncertainty and capitalise on emerging social and economic opportunities (Campbell *et al*., 2003). The main forms include land use intensification, sedentarization, land subdivision, employment, retail, trade, and cultivation (Ogutu *et al*., 2014). Although it has been established that livelihood diversification can either reduce or actuate households' vulnerability to poverty (Canagarajah *et al*., 2001), the extent to which they affect household resilience is only marginally understood. This raises the possibility that the impacts of current development planning frameworks, policies and programmes tailored to enhancing adaptation capacity of affected communities cannot be determined to the lowest household unit, an eventuality that defies the principle of equality in distribution of opportunities for social and economic advancement.

Further, the current landscape of literature on livelihoods of stressed ecosystems fall short of providing a comprehensive picture of their logical connections with drought resilience for households. This is because a vast number of them are disciplinary scope-tailored to an aspect of the problem such as biophysical conditions, marketing and commercial activities (Galvin, 2009) or not linked to socio-ecological dynamics of the ecosystems (Fortuin *et al*., 2011; IPCC, 2014; Leslie *et al*., 2015). Studies on resilience are only beginning to appear in the domains of ecosystem livelihoods analyses (Shiferaw *et al*., 2014) although their methodological approaches do not embrace the totality of the Geographic Information Systems (GIS) in the locales.

Still, existing analyses of livelihood diversification strategies by communities in compromised ecological conditions in East Africa have been overtly inconclusive. There is also lack of consensus in the conclusions drawn from empirical studies on whether the livelihood diversification approaches by the pastoral people are expressly for purposes of economic sustainability in the wake of ecological hazards (McCabe *et al*., 2014). From this review, studies assessing drought risk focus on either biophysical impacts or livelihood diversification, using well-established methodologies are lacking. Thuo (2011) found a significant relationship between enterprise diversification and household food security among small-scale sugarcane farmers in Muhoroni Division, Kenya. She also noted that ‘the higher the extent of farm enterprise diversification, the higher the food security status level’.

2.4.3 Policy Frameworks for Promoting Drought Resilience in Kenya

Kenya policy response to drought management is informed by the process of domestication of the global United Nations Convention to Combat Desertification (UNCCD) ratified in 1997. One of the main commitments of the Parties to the Convention is to develop National Action Programme, which serves as guiding framework for the implementation of the Convention at national level. Kenya’s national action programme identifies soil degradation due to overgrazing as one of the challenges facing the drylands. The unplanned shift from pastoralism to arable agriculture as well as subdivision of land has resulted in widespread environmental degradation and blockage of the natural migration routes of both livestock and wildlife (GoK, 2002).

The Sendai Framework for Disaster Risk Reduction 2015-2030 adopted in March 2015 in Sendai, Japan provides an overarching framework for responding to drought disasters. The framework succeeds the Hyogo framework and aims to strengthen country response to disasters, including recovery, rehabilitation and reconstruction phases. It focuses on measures to minimize loss of lives, livelihoods and property; strengthen resilience through prevention and reduction of hazards, exposure and vulnerability as well as better preparedness and recovery (UN, 2015). The framework identifies four priority areas for action namely: (i) understanding disaster risk, (ii) strengthening disaster risk governance to manage disaster risk, (iii) investing in disaster risk reduction for resilience, and (iv) enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction. Implementation of the framework depends on a good understanding of the prevailing conditions through assessment of disaster risks, vulnerability, capacity, exposure, hazard characterise and sequential effects at relevant social and spatial scales.

At the national level, the first drought policy was initiated in 1992 when the drought contingency action plan was implemented through the national disaster management programme under the then Department of Relief. In 2007, the Sessional Paper No. 8 on national policy for sustainable development of arid and semi-arid lands was formulated as framework to protect economic, environmental and social facets of communities affected by drought. The essence of the policy was to reduce vulnerability of poor people to climate shocks, through strengthening adaptation capacities (GoK, 2007a).

This policy resonated well with the needs of the ASAL communities but weak implementation compromised its effectiveness. It was reviewed again in 2015 even before being implemented. At the same time, the national disaster management policy was developed to strengthen preparedness of the government, communities and other stakeholders on reducing the effects of environmental hazards (GoK, 2007a). Its aim was to establish disaster management institutions, partnerships and networks, integrate disaster risk reduction in the development process, and foster the resilience of vulnerable populace through Early Warning Information.

Following the 1979 - 1980 drought, the government developed the Sessional Paper No. 4 of 1981 on National Food Policy (GoK, 1981) in which it committed to *inter alia*, "maintain a position of broad self-sufficiency in the main foodstuffs to enable the nation to be fed without using scarce foreign exchange on food imports, and to achieve a calculated degree of security of food supply for each area of the country" (GoK, 1981). Subsequently, Food and Nutrition Planning Unit under the then Ministry of Planning and National Development was mandated to coordinate food security issues across the various players. Thereafter, the government has consistently recognised that drought compromise prospects for food sufficiency particularly in the pastoral ecosystems, and established various structures such as drought contingency planning and monitoring mechanism within its administration to address this matter.

The government put in place policies to address the challenges of drought. In 2015, a common programme framework for ending drought emergency (EDE CPF) was developed to address drought emergencies in ASAL counties by facilitating cooperation and synergy across sectors, actors, geographical areas and levels of operation. EDE has six pillars; peace and security, climate-proofed infrastructure, human capital, sustainable livelihoods, drought risk management and institutional development and knowledge management (GoK, 2015). The first four pillars aim to accelerating investment in drought prone areas to foster development, while the second two aim to strengthen institutional and financing frameworks for drought risk management (DRM). EDE is builds on the premise that investing in the foundations for development upon which other interventions are implemented and strengthening institutions for DRM creates sustain results beyond project interventions (Carabine et al., 2015). The National Drought Management Authority (NDMA) has a mandate to oversee implementation of the EDE CPF, the national initiative folded into the larger regional efforts to better manage the underlying causes of droughts.

The sector plan for drought risk management and the (EDE) 2013 – 2017 were developed as a government response to the 2008-2011 drought and the need to roll of the Vision 2030 Development Strategy for Northern Kenya and other Arid Lands developed in 2012. An object of the Vision was to ensure food and nutrition security in areas that are susceptible to drought, where people's access to and control over critical livelihood resources such as land is insecure, and where climate change will increase unpredictability (GoK, 2012).

The plan sets to eliminate the worst effects of drought through strengthening people's resilience to drought, improving monitoring of, and response to drought emergency. It recognizes the unique characteristics of ASALs to callous climatic conditions, which diminish or degrade natural resources. Scarcity of pasture and water undermine productivity of pastoral and agro-pastoral livelihoods and exacerbate food insecurity. The Plan is sentient to the fact that pastoral system is undergoing transformation towards more commercialisation and individualisation, resulting to widening the gap between wealthier and poorer households. Transformation is further aided by changes in the rangelands, resulting from disruption of traditional seasonal transhumance patterns, the expansion of community conservancies, human population pressure, and the spread of invasive species. However, the Plan fails to recognize the transformation of pastoral systems due to adoption of different livelihood systems through diversification.

These frameworks and instruments spell out broad outlines for disaster risk reduction at the international, national and local levels. Implementation of these frameworks demands that governments consider their national and local circumstances in designing response measures. Although biophysical and livelihood are important elements in determining local circumstances, they have not been explicitly addressed by these frameworks. In the wake of these imperatives, this thesis is grounded on the premise that analysing the utility of livelihood diversification as the route to household resilience to drought evokes the need to pursue a conceptual and methodological standpoint sufficiently broad in its disciplinary constituents if the results are to foster a renewed policy-practice narrative on the subject. As elaborated in the next chapter, it is against this backdrop that the study has incorporated a mix of positivist and phenomenological approaches in its design to find answers to the family of ecological, social and economic aspects of the variables of interest.

2.5 Theoretical Underpinnings

2.5.1 Social Ecological System Theory

The Social-Ecological System (SES) theoretic framework founded on the general systems theory postulated by Von Bertalariffy in 1965 guided this research. The general systems theory expounds on properties, principles and laws that characterize any form of system irrespective of character. SES refers to the system made up of organized assemblies of humans and non-human life forms in spatially determined geographical settings (Holling, 2011). In this context, a system is defined as an entity with certain properties that are differentiated from the surrounding environment. An entity interacts with each other and with the environment generating system properties being described and investigated. Thus ecological systems are intertwined and are affected by social system and recent application identified management practices, adaptation, and resource use as important elements for integrating social and ecological systems ((Anderies *et al*., 2004).

The inclusion of adaptation element suggests that SES is non-static and prone to shocks. Their stability much depends on their ability to withstand shocks or resilience. Resilience refers to a system's capacity to experience perturbations while retaining its essential functions, structure, feedbacks, and identity (Ostrom, 2009). It is a continuous cycle involving a series of disruption, reorganization, and renewal of a system, with the potential to shift it to new phases depending on the durability and persistence of disturbance.

SES represents an integrated system of human and biophysical systems with feedback mechanism and interdependence (Adger *et al*., 2005) as is often the case in most rural societies whose livelihoods depend on ecosystems. Because of this, SES theory is widely used to understand the complex and dynamic interactions between human and environment systems regarding adaptation, transformation and resilience (Ostrom, 2009; Walker *et al*., 2006), therefore forming a central aspect when analysing human-ecological systems in changing environments. If one part of the SES is known, the knowledge can be used to gain understanding of another part. Thus, if the integrity of the ecological system is compromised, the effects are manifest in the social system and vice versa. Adopting a holistic and integrated approach is essential in assessing a SES system as a complete functioning unit. Since SES are open systems, political and economic forces, and large-scale biogeochemical conditions often influence their interactions (Chapin et al., 2009). Though SES has gained wide acceptance across many disciplines, it is criticised on three main grounds; failure to account for politics, lacks consideration for agency, and fails to explain circumstances where the systems resilience collapses (Pelling, 2011).

According to Ostrom (2009), there are two components of SES namely human and ecological. The human component encompasses individuals, communities or institutions through which social processes such as demography, livelihood activities, and technology are organized, while the ecological component includes soils and atmospheric elements that support nutrient cycling, species interactions and evolution. The two components interact to produce management practices, adaptations and resource use. Some SES interactions produce sustainable outcomes while others collapse. Thus, users of the ecological system will adopt different management practices when they observe a decline in an ecological resource. Analysis of the SES interaction can be achieved using a set of variables identified within four core subsystems resource units, resource system, governance system and users.

Lislie *et al*. (2015) conceptualizes SES as an interaction of four components of actors, governance system, resource unit and resources system mediated by social, economic and political settings. The actors represent resource users who extract specific resource units from a resource system under certain rules and procedures in the context of ecological system and broader social-political-economic setting (McGinnis and Ostrom, 2014). The sustainability of SES depends on how the interactions are maintained to meet human and nature needs.

According to Walker *et al.* (2004), whenever a SES is disturbed, it exhibits dynamic characteristics following an adaptive cycle with four phases: a growth and exploitation phase, a conservation phase, a chaotic collapse and release phase, and a reorganization phase. The reorganization phase produces a subsequence a growth and exploitation phase either similar to the original one or total different. They further argue that SES dynamism depends on its resilience, adaptability and transformability. Resilience refers to capacity of SES to absorb disturbance and reorganize while undergoing change to retain the same functioning, structure, identity, and feedbacks. Besides capacity to absorb shocks and continue to function, SES resilience is determined by its capacity to re-organize and develop under shock (Folke, 2006), a key measure of sustainability. Thus, when disturbed, resilient SES exhibit greater potential to create opportunities for innovation and development, while vulnerable ones weaken even under small disturbance with social consequences.

While traditional school of thought assumed SES as stable and infinitely resilient where resource flow was naturally controlled, Holling (1973) argued that all SES are transient and often shift to different regime. Regime change is triggered by stochastic events external to the SES, in the form of fast large shock or slow gradual change. Whichever the form regime change takes place when a certain threshold is reached at which point, the SES is forced to re-organize its dominant elements. Unlike fast large observable shocks, slow gradual shocks erode the core elements of the SES unnoticed until the actual regime shift occurs as a surprise. In pastoral SES where livelihoods of the actors are closely intertwined with resource systems, external perturbations like drought potentially induce significantly transformation in the system insidiously (Gallopín, 2006).

2.5.2 Sustainable Livelihood Framework

The sustainable livelihood framework is widely used to contextualize people's relationship with their environment and economy (Scoones, 1998). A livelihood is viewed as the means of gaining a living, encompassing livelihood capability, and tangible and intangible assets. Sustainability is linked to the ability to cope with and recover from stresses and shocks as well as to maintain the natural resource base. A livelihood comprises the capabilities, assets (including both material and social resources), and activities required for a means of living (Chambers & Conway, 1992).

A livelihood is sustainable when it can cope with, and recover from stress and shock; maintain or enhance its capabilities and assets without undermining the natural resource base (Carney, 2002). Three elements are important to the current study: vulnerability context, livelihood assets, and livelihood strategies. Livelihood assets are categorized into five: natural capital, human capital, physical capital, financial capital, and social capital. Natural capital refers to stocks from which resource flows and services useful for livelihoods are derived. They include both intangible public goods and divisible assets.

Human capital comprises skills, knowledge, ability to labour and good health that together enable people to pursue different livelihood strategies. Physical capital is the basic infrastructure and producer of goods needed to support livelihoods. Financial capital comprises resources that people use to achieve their livelihood objectives and consists of available stocks and regular inflows of money to individuals, while social capital refers to social resources upon which people draw in pursuit of their livelihood objectives and include networks and connectedness, membership of formal groups and social relationships (Scoones, 1998).

Within this framework, vulnerability is viewed as a broad concept encompassing livelihood assets and their access, and vulnerable context elements such as shocks, seasonality and trends. It also encompasses institutional structures and processes. This approach underlines the multiple interactions that determine the ability of a person, social group or household to cope with and recover from stresses and shocks such as drought. Application of the framework enables an assessment of only positive outcomes from pursuing certain strategies. For example, the effect of livelihood diversification on sustainable use of natural resources can be analysed to determine its effectiveness in reducing household vulnerability to hazards such as droughts, floods or landslides (Cannon *et al.*, 2003).

A pastoral livelihood is considered sustainable if it can cope with, and recover from climatic shocks like drought; maintain its capabilities and assets, and does not undermine the natural resource base. This framework was selected for the current study because of its flexibility in the number of variables to be included in the analysis.

As such only those trends and shocks that are important to a livelihood can be concentrated on understanding the impact of these factors and how negative aspects can be minimised. Such analysis requires prior understanding of the local livelihoods and the factors that constrain them from achieving their objectives. This can be realised through social analysis.

2.6 Conceptual Framework

An integrated conceptual framework was adopted to guide the logical thinking of the interaction between climate induced drought and changes in livelihoods (Figure 2.1). The framework is based on the theoretical frameworks presented in Section 2.5.1. The socio-ecological system of the pastoral communities comprises of the interaction of social and ecological process which give rise of economic process. It is conceptualized that while drought increase pastoral vulnerability, livelihood diversification strengthens their resilience to cope with drought.

Social processes taking place in Oltiasika are driven by human activities and heavily influenced by demographic and land use changes. Therefore, the variables of interest in understanding the social process are changes in human population and settlement patterns from a mobile system to a more sedentary settlement. Ecological processes describe changes in biophysical conditions of Oltiasika, measured by availability of natural resources to sustain pastoralism. These proceses represented by changes in the vegetation conditions over a period as measured by the Normalized Vegetation Difference Index.

This conceptual framework assumes that the interaction between the social and ecological processes has over the years been sustainable and social processes took place within the available natural resources. In other words, the number of people and land use practices could be supported by the ecological systems. In most dryland area, livestock rely on pasture for their diets, and the quality and quantity of pasture and water is determined by rainfall. According to Hesse and Cotula (2006), the natural resources are managed through common property regimes where access is negotiated and dependent on reciprocal arrangements. The sustainability of the pastoral system depends on the balance between available pasture, number of livestock and people's activities. If the number of livestock exceed the carrying capacity of the area, there is danger of over-grazing if their movement is constrained. If there are too few animals, they may not meet the needs of the household. If the household is too small, it may not manage the livestock properly. If the quality and quantity of pasture deteriorate because of drought, the pastoralists lose their livestock and become destitute. Mobility of livestock is a central strategy used by pastoralists to maintain the balance.

Climate induced drought represent an external shock to the social-ecological system. Drought as measured by standardized precipitation index influence the availability of natural resources upon which livestock depend on. Frequent and severe drought affect the ability of the pasture to regenerate and reduce its availability by the livestock. Pronged drought can also result in but livestock mortality, thereby disrupting the dominant livelihood type in the area.

Drought causes disequilibrium in this interaction through reduction of biophysical ability to supply services to sustain a livelihood. This disruption necessitates community livelihood diversification through coping and adaptation. Coping refers to those measures meant to cushion communities from adverse impacts in the short-term and are generally reactive while adaptation tend to be long-term and proactive in nature (IPCC, 2014).

Depending on the severity of the shock, households employ a wide range of coping strategies, which range from reduction in selling of food, reduced consumption, and increased borrowing to higher rates of seasonal out-migration, default on loans, withdrawal of children from school, distress sale and liquidation of productive assets such as livestock, land, trees and other assets.

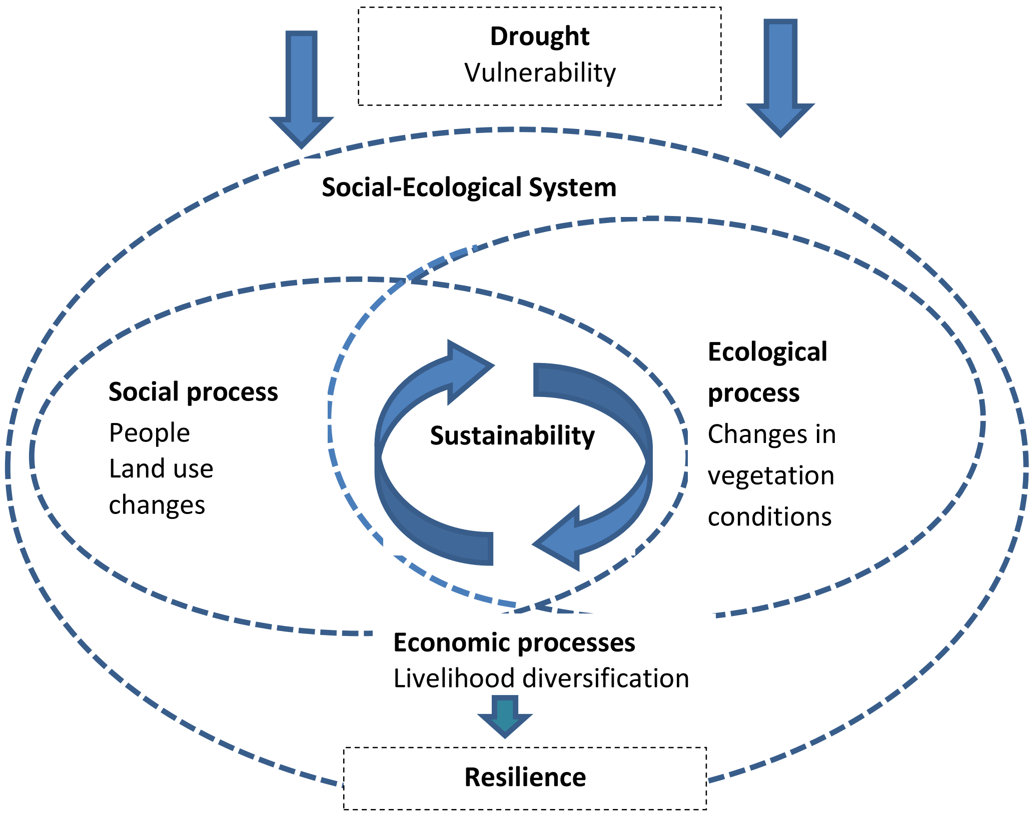

Figure 2. 1: Conceptual Framework Depicting Social-Ecological System in Oltiasika

They do so by first cutting expenditure on 'non-essential' items such as clothing, social functions, food and medical treatment, adjustments in food balance and more progressively to reliance on public relief and safety-net programs and exploitive environmental management practices. Drought is also expected to result in livelihood diversification among household by increasing the diversity of activities used to generate income. It is assumed that households with greater diversity of income sources have higher capacity to survive a drought. Household resilience to drought is measured by the capacity of the household to meet food requirements under extreme conditions. This conceptual framework was deemed most relevant for the study since it integrated both biophysical and human systems, drought and responses.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter describes the methods and procedures used in carrying out the study. It begins by giving a description of the study area in terms of location and physiography, geology and soils, climatic and vegetation conditions, social-economic and demographic characteristics. It then outlines the study design, sampling methods, and techniques used in data collection. It concludes with a description of the procedures and techniques used to analyse data.

3.2 Study Area

3.2.1 Location of Oltiasika

The study was carried out in Oltiasika Division, Kajiado County, within the Chyulu-Amboseli ecosystem. The area is located within latitudes 2.21º S and 2.77º S and longitudes 37.40º E and 37.94º E with an area of 1,352 square kilometres (KBNS, 2010). The division is divided into two locations – Mbirikani and Oltiasika. The study area is about 6 km from Amboseli National Park (Maclennan, Groom, Macdonald, & Frank, 2009), with the boundaries coinciding with those of Mbirikani Group Ranch (Plate 3.1). The area is an important wildlife migratory corridor for animals moving between Amboseli and Tsavo National Parks. The physiography of the area is influenced by the Chyulu Hills, which bound the area to the east and the slopes of Kilimanjaro located to the southeast.

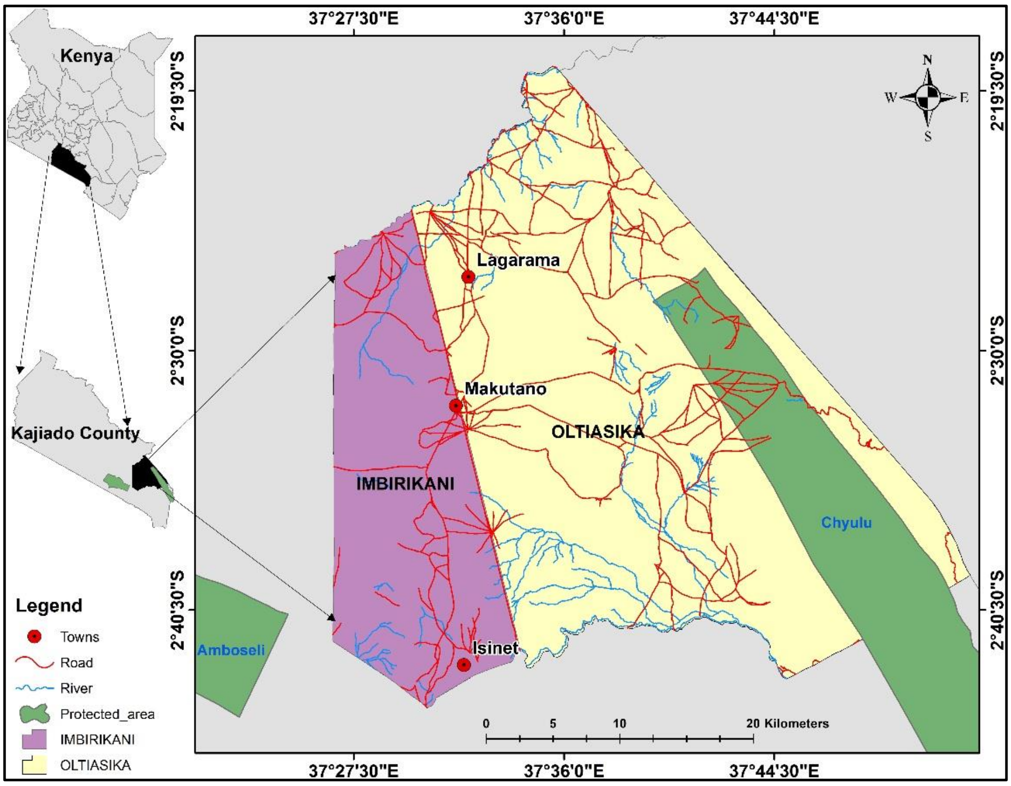

Plate 3. 1: Location of Oltiasika Area

The area is low-lying with small interruptions of hills towards the western and northern parts. The digital elevation model shows that the land slopes from a low altitude of 990 metres above sea level at Memerush to a high of 1909 metres at the Chyulu Hills. The Chyulu Hills form the rain shadow for the Mbirikani Group Ranch. The hills comprise a chain of relatively recent volcanic highlands formed from eruptions that took place less than 10,000 years ago (Pócs & Luke, 2007).

3.2.2 Geology and Soils

The Chyulu Hills consist of an upper level plateau rising to an altitude of 2000 m, surrounded by lava flows and a mixture of smaller lava ridges, uplands and foot slopes. To the north-west of the Hills volcanic uplands are prominent, rising to an altitude of about 1200 m while to the south and west are erosional plains over gneissic basement complex; these extend south along the western boundary of Mbirikani. These flat or slightly undulating plains are bound in the south by another series of volcanic uplands, which are studded with small irregular outcrops of basaltic boulders. This unit forms the southern boundary of Mbirikani and extends south to the foothills of Kilimanjaro.

In the central part, erosional plains form a lower-lying trough (1100-1150 m; units 14 and 15), merging with the Chyulu foothills to the east (Plate 3.2).

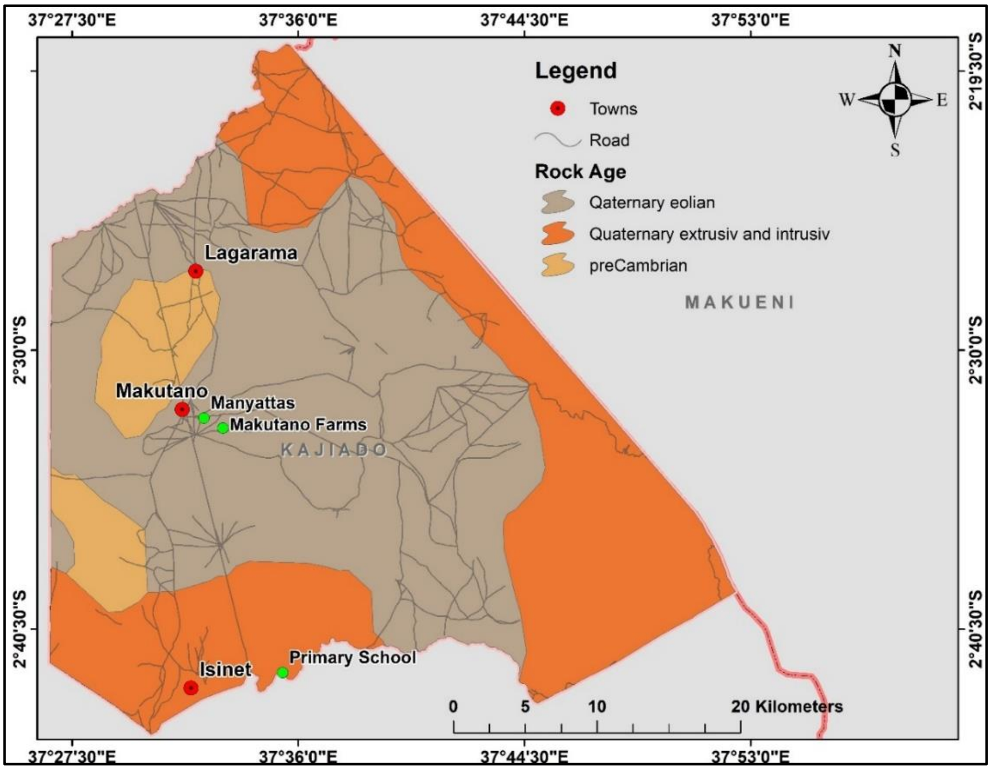

Plate 3. 2: Geology of Oltiasika Area

The physiography of the area has resulted in a wide range of soils, most of which are deep and fine-textured. On the volcanic uplands and plains, the soils range from stony Cambisols on the upper slopes to dark, cracking Vertisols in bottomlands and valleys (Plate 3.3).

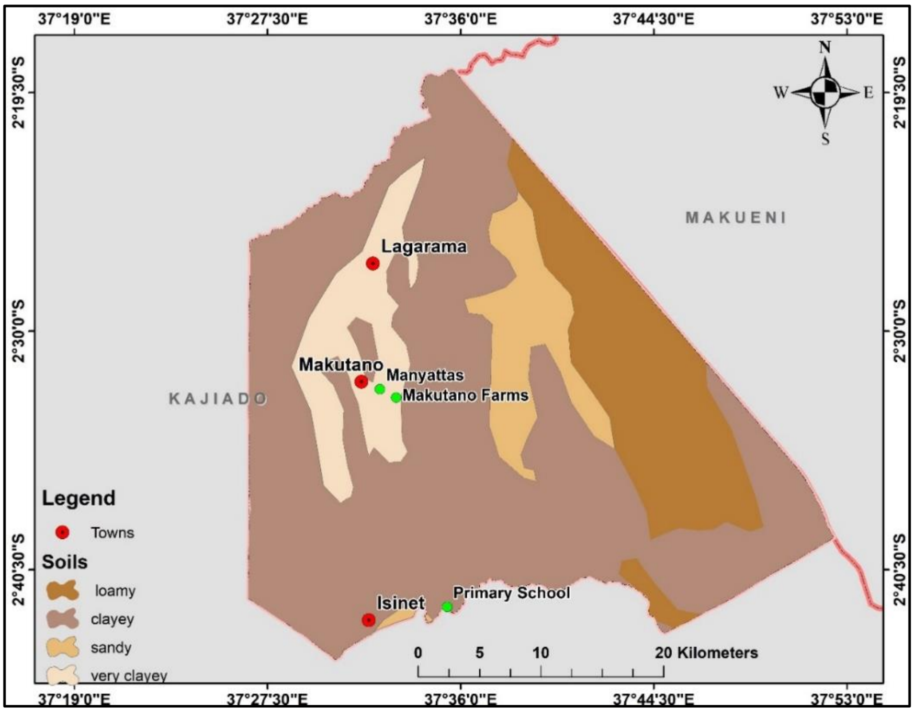

Plate 3. 3: Soils types of Oltiasika Area

The main soils are Lithosols on lava flows, Andosols on coarse ash deposits and deep Luvisols on the flatter plains (Exploratory Soil Map of Kenya: KSS, 1982). Soils overlying gneissic basement complex are generally sandy, well drained and susceptible to erosion. The plains in the central, driest part of feature dark clayey and very clayey soils with vertic and saline-sodic properties.

3.2.3 Climate and Vegetation Conditions

A great part of Oltiasika Division lies within agro-climatic zones LH3-4 (medium potential to semi-arid) to LM6 (very arid) (Plate 3.4). The northern and the eastern part are situated in the semi-arid zone; the remainder in the arid zone. Most of the study area falls within "Lower Midland Ranching Zone", where rain fed cropping will succeed only in seasons in which rainfall is exceptionally good, i.e. above average and well distributed (Jaetzold, Schmidt, Hornetz and Shisanya, 2007).

The areas receive distinct bimodal rainfall with "first rains" falling from October to December and the "second rains" falling from March to May. There is a short dry period during January and February and along dry season from June to early October. The annual potential evaporation is about 1950 mm, giving a moisture Index of 0.31

for the mean annual rainfall of 616 mm at Sultan Hamud meteorological station near the study area.

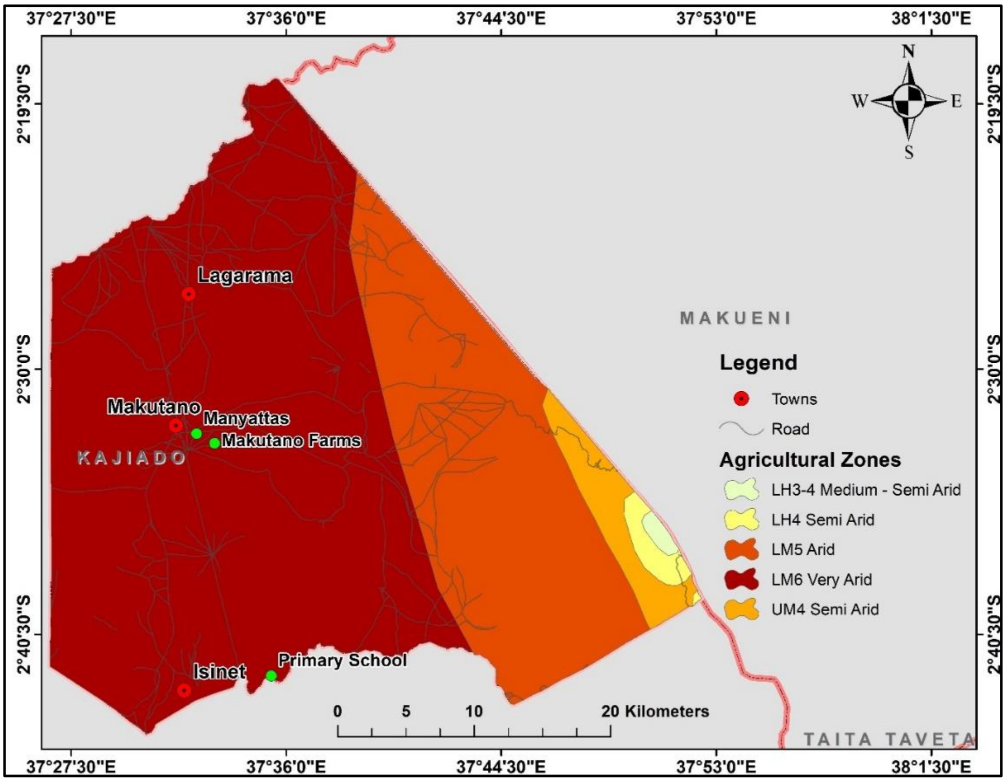

Plate 3. 4: Agro-climatic zones of Oltiasika Area

The area has a history of most destructive droughts that have been manifested in the Horn of Africa (ODI, 2010; Notenbeart et al., 2012; Okoti et al., 2014). In the past century, droughts were recorded in 1933 -1935, 1943 - 1946, 1948 - 1949, 1952 - 1953, 1960 - 1961, 1972 - 1976, 1983 - 1984 and 1994 - 1995 (Campbell, 1999). Severe droughts were experienced in 2001 and 2005 - 2006 (Ojwang et al., 2006). The severest drought in the 33-year study occurred in 1973 – 1976 with the most recent drought in in 2009. Wildlife and livestock numbers fell during this drought and rose again in the ensuing wet years (Western, 1994). Recent drought occurred in 2008-2011 that resulted in livestock mortality and decline in production of meat, milk and other by products (Demombynes & Kiringai, 2011).

The low-lying areas are semi-arid to arid, whereas the Chyulu Hills area are semi-humid to semi-arid with an annual rainfall range of 600 mm at the western foot slopes to 1400 mm at the hilltops. Frequent drought experienced in the area have made it suitable for conservation and tourism activities, although fragmentation of the wildlife habits in recent years has diminished the dispersal area and reduced wildlife movement.

The area is characterized by spatial and temporal variation in hydrology. The swamps that form the southern boundary of the area are important sources of permanent water. Those to the west drain into Lake Amboseli; the rest drain into the Loolturesh River and thence into the Tsavo River. Pools found in riverbeds following the flash floods that occur after heavy rainfall are also important sources water. Plate 3.5 shows the hydrological model of the area based on a digital elevation model.

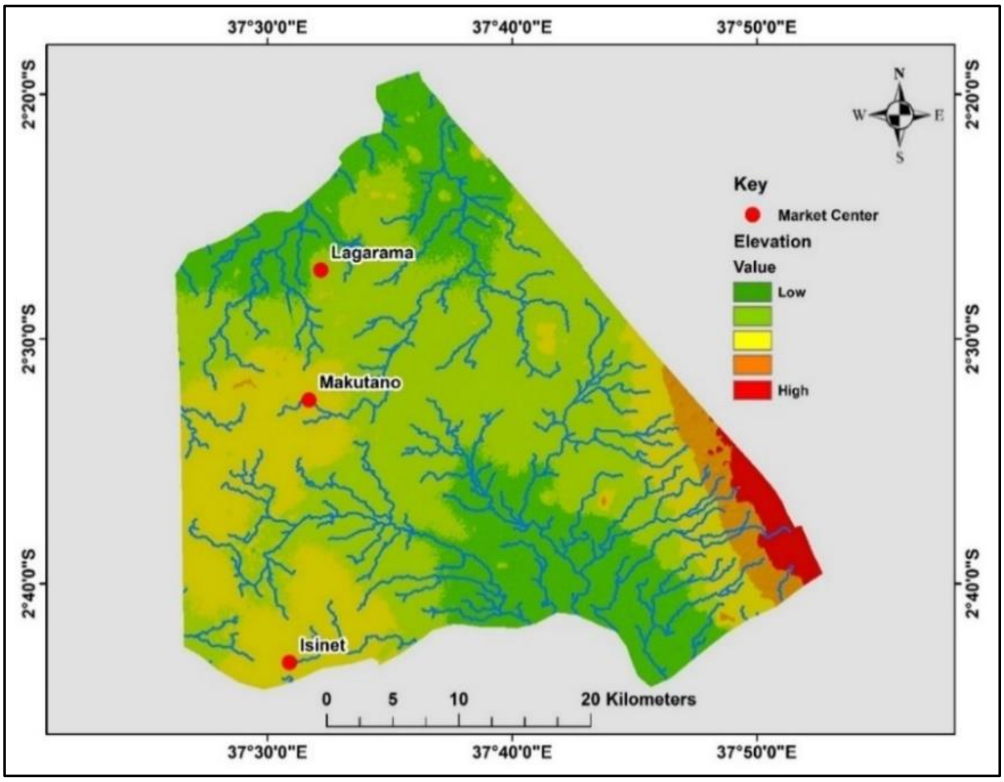

Plate 3. 5: Drainage Network of Oltiasika

According to the model, the area around Makuato is on a higher elevation forming a watershed for rivers towards the North and the Southern Eastern. The area has poor distribution of permanent water with surface water only found in few permanent springs, which flow through a few swamps; the Kikarangot River along the Southern boundary of the ranch and a water pipeline running south to north in the western quarter of the ranch. These are important sources of water sources during dry spells.

Large part of the study area comprises of treeless savannah shrubs (Plate 3.1). Woody cover is found on units over basement complex, such as the northern plains and uplands. The southern fringe of the area is also more wooded with extensive Acacia tortillls woodlands on the lacustrine plains. There are also patches of acacia woodlands along the Kiboko River. Dense forest occurs only on lava flows in the Chyulu Hills.

Although perennial grass species made up most of the grazable biomass in most landscape, annual grasses and forbs are important but variable components of the herbaceous layer. *Eragrostis Cillanensis*, *E. tenulfolla, Dactyloctenium aegyptiaca, Aristida adscensionis* and *A. adoensis* contributed substantially to the biomass in good rainy seasons, as did a plethora of annual herbs. Several grassland types also included dwarf shrubs and perennial herbs, many of which are important browse plants for sheep and goats (de Leeuw and Chara, 1985; Kamau, 1986). The productivity of the different grassland types was much confounded with rainfall events (i.e. localised showers or storms) and with past. The main vegetation types in the study are presented in Plate 3.6.

Towards the north and northeast to the Chyulu Hills, the area is dominated by open grasslands. Along the spine of the hills above 1,800 metres above sea level, rough grassland and thicket pave the way to patches of montane forest; the largest tract of forest is around the highest peaks in the central-southern portion. Characteristic trees include *ficus spp*., *neoboutonia macrocalyx, tabernaemontana stapfiana, prunus africana, strombosia scheffleri, cassipourea malosana, olea capensis* and *ilex mitis*, with islands guarded by *erythrina abyssinica*. Lower down, there are areas of *juniperus procera* forest and, particularly on lava flows, forest dominated by the blue-stemmed *commiphora baluensis* (the hills were occupied by peasant farmers until 1988 when they were relocated to pave the way for the Chyulu National Park, causing resentment among those relocated. The park is located along the eastern part of the Chyulu Hills while the area surrounding the hills are classified as arid or semi-arid Northern Acacia-commiphora bushland and thickets (Burgess et al., 2004).

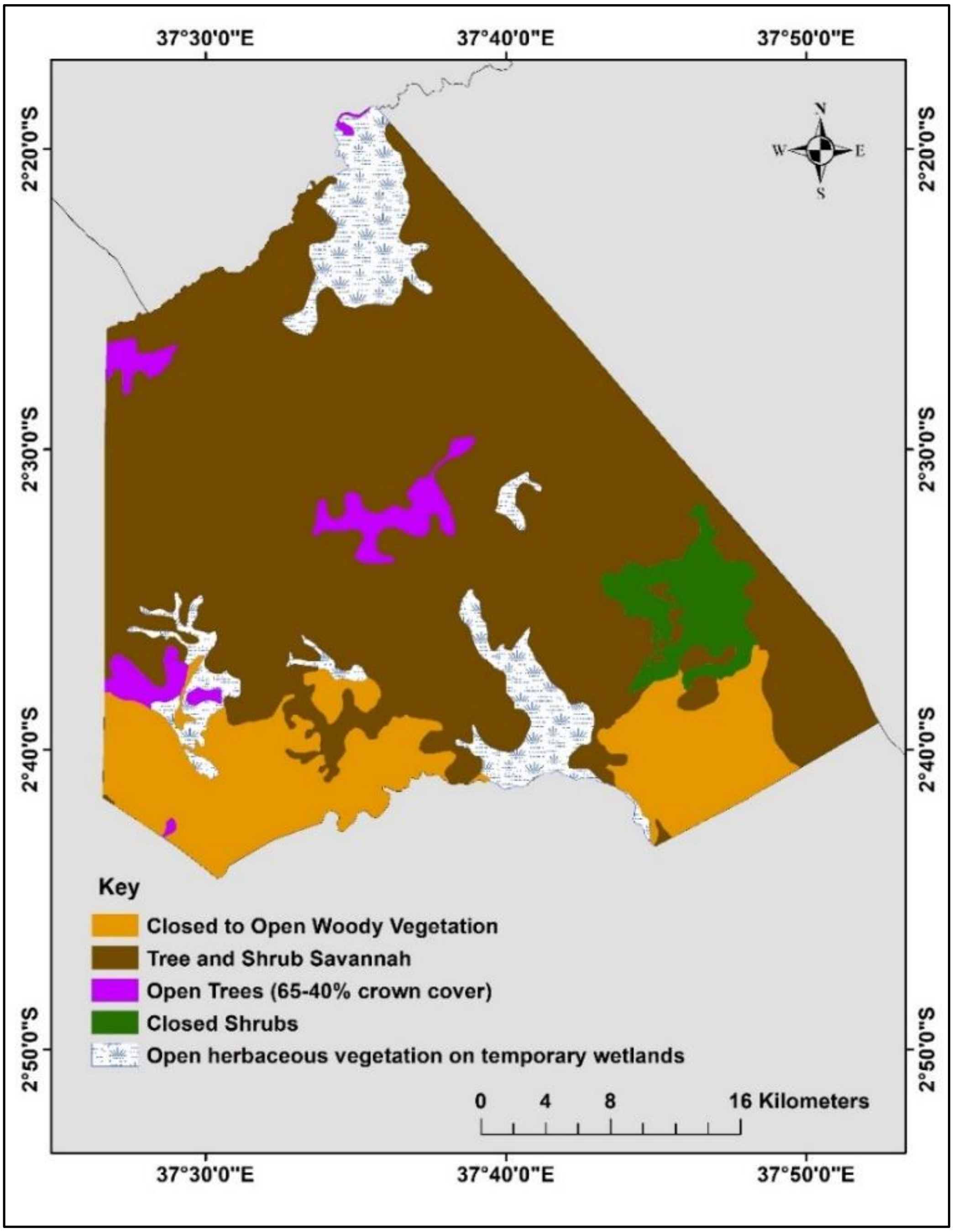

Plate 3. 6: Vegetation Conditions of Oltiasika Area

Chyulu Hills provide wet-season grazing for Maasai pastoralists from the nearby group ranches and are an important corridor for elephants migrating from Tsavo into Amboseli National Park. Adjoining the study area is the Amboseli basin; a Pleistocene lakebed that provides a permanent water from Mt. Kilimanjaro. Because of this, it is a critical dry season grazing area, attracting large populations of wildlife, which is the foundation of tourism (KWS, 2008). The vegetation on the ranch varies greatly but is dominated by sparse flat savannah grasslands.

3.2.4 Social spatial organization of the Maasai people

Oltiasika is inhabited by the Maasai community who form a distinctive social unit sharing a culture, language and social structure. Maasai social-spatial organisation is composed of five basic units: household, boma, unit/locality, section and Maasai society. The household is the primary unit of production, comprising of husband, wives and unmarried children, often extend to include married sons and their wives, the husband's mother (and his siblings) if their father is dead, and impoverished dependants. In the past, Maasai households lived together in large compounds or bomas (enkang) made up of 6 to 12 households (Jacobs, 1965). With increasing sedentary and shift towards commercial production, the average size of a boma has declined and the single family boma has become common. Bomas were grouped into larger units, which controlled local resources such as grazing and watering facilities. A unit was a cluster of bomas, usually located within a kilometre of each other. The term *elatia* refers to a group of neighbours.

Each Maasai producer belonged to a locality, which he regarded as his home area or emparnat. A Maasai is identified primarily with his oloshon or section, a subtribe with a unified political and administrative structure. A section had a fixed territory that was collectively owned by section members prior to the establishment of group ranches. The territory of each section was large enough to provide adequate pasture both in normal and dry times, but not during extreme drought. The introduction of administrative unit curtailed the free movement of a producer and his household. While it was easy for him to move from one boma to another, sectional boundaries made such movement difficult (Jacobs, 1965).

Political the Maasai were organisation in age-sets made of circumcised boy who had to pass through the stages of warrior (moran), junior elder, senior elder and retired elder, each stage lasting about 15 years. The senior elder age-set was responsible for providing traditional administration. A man's age-set status continues to affect his political status, although this is increasingly offset by level of education (Grandin, 1991).

Clan (olgilata) is a group of people who recognise descent from the same (putative) ancestor. Maasai clans are patrilineal; a child belongs to the clan of his father and remains a member for life. Cattle of clan-mates have the same basic branding (with each producer adding his unique identifier). Clan-mates have very strong mutual aid obligations. For example, when a man dies young with no brothers, his clan-mates are required to help raise his children and tend his livestock. Clan-mates are bound to come to the aid of a Maasai becomes impoverished through drought, raid, or other misfortune. Clan-mates also supported their members during marriage by participating in negotiations or obtaining the necessary bride-price; and were involved in disputes resolution (Bekure *et al.* 1991). There are five major clans and about 40 sub-clans in Kajiado Country. The clans are grouped into two moieties, one called the house of the red oxen and the other of black cattle (Odomong'i and Orok-kiteng') each descended from one of the two wives of the first Maasai ancestor. The Kaputiei clan is the dominant clan in the study area.

The 2009 National Census puts the population of the study area at 15,451 and 3,110 households (KNBS, 2010), giving a population density of 11. The distribution of population by administrative location is shown in Table 3.1.

Table 3. 1: Population of Oltiasika Area, 2010

Administrative location	Area (km^2)	Population	No. of households	Density Persons/km^2
Mbirikani	339.8	8702	1914	26
Oltiasika	1012.4	6749	1296	6
Total	1352.2	15451	3210	11

Source: KNBS, 2010

The area is sparsely populated, a common characteristic of Kenya's ASAL areas. The Chyulu-Amboseli ecosystem is very dry and pastoralism is the main land use with household income derived from livestock sales. Soon after independence, the government piloted the concept of group ranches in Kajiado County with the goal of boosting the off-take of livestock for commercial purposes and as a means of providing communal essential development services, such as veterinary and water. Mbirikani Group Ranch falls within the study area. The group was formed in 1970 with membership of 4,650 adult household heads. Pockets of small-scale and localized crop farming takes place in riverbeds at Isinet, as well as along the Noolturesh pipeline. Crop farming is mainly practised by migrations from Kikuyu and Kamba ethnic groups and from neighbouring Tanzania (Kenana et al, 2013).

Livestock such as cattle, goats and sheep are the primary source of income for the Maasai. Among the Maasai, livestock is a social utility and plays an important role in the Maasai economy. Livestock are traded for other livestock, cash or livestock products such as milk and siege. Individual, families, and clans established close ties through giving or exchange of cattle. Livestock products are sold to other groups in Kenya for the purchase of beads, clothing and grains. Cows and goats are also sold for uniform and school fees for children. It is now common to see young Maasai men and women in major towns and cities of Kenya selling, not just goats and cows, but also beads, cell phones, charcoal, grain among other items. Further, the livestock were relied upon for protein and caloric needs through the supply of meat, milk and blood (Grandin, 1991). More recently, the Maasai have grown dependent on food produced in other areas such as maize meal, rice, potatoes, cabbage. The Maasai who live near crop farmers have engaged in cultivation as their primary mode of subsistence. In these areas, plot sizes are generally not large enough to accommodate herds of animals, forcing the pastoralists to farm.

3.3 Study Design

A cross-sectional research design provided a framework for data collection and analysis for this study. This type of research design entails the collection of quantitative or qualitative data on more than one variable and at a single point of time to detect patterns of association between them (Bryman, 2004). Quantitative research leads to confirmation or rejection of a pre-determined hypothesis, meaning it is hypothetico-deductive in nature, while qualitative research is concerned with those phenomena hard to measure and focuses on giving meanings, social context, and narratives and experiences (Denzin and Lincoln, 2005).

Information obtained from quantitative research was triangulated with that from qualitative research and vice versa to corroborate the data and enhance its validity. Since the two research approaches are complementary, they were integrated at every stage of the methodology. This research design ensured variations of the phenomena of interest namely drought, vegetation, and livelihoods were examined. The study adopted standard measured of the concepts of drought, vegetation changes and livelihood diversification toward ensuring greater reliability of the results. Data sources for drought and vegetation changes were obtained from satellite-based instruments and observations from a weather station an indication of high validity. The validity of survey data was checked by collaborating with secondary sources.

3.4 Sample Size and Sampling Procedure

3.4.1 Target Population

All 3,210 households in the Oltiasika Division, irrespective of their livelihood activity, constituted the study population. A household was the unit of analysis and because all households in Mbirikani Group Ranch were under a common management and had common norms and culture, the population was considered homogenous. Registration in Mbirikani Group Ranch and residence within the division were the two criteria used to include units to the sample, while households which were less than five years old in the study area had no prior experience of the subject under inquiry, and therefore were excluded from population. Because this study sought to investigate perceptions of, and experiences, on drought and changing livelihoods, respondents younger than 24 years were dropped from the sample. These were assumed too young to have experienced impacts from droughts to occasion a shift in their livelihood system.

3.4.2 Sampling Size and Sampling Procedures

Two types of sampling were carried out in this study. The first sampling focused on the sites for assessing the biophysical changes taking detection in the area. Four sites namely; Makutano farms, Manyattas, Makutano centre, and a primary school were sampled on google earth based on data availability over different time periods and where the changes were readily detected (Plate 3.7). These sites provided information on changes in cultivated land, settlement patterns, urbanization and expansion of education facilities.

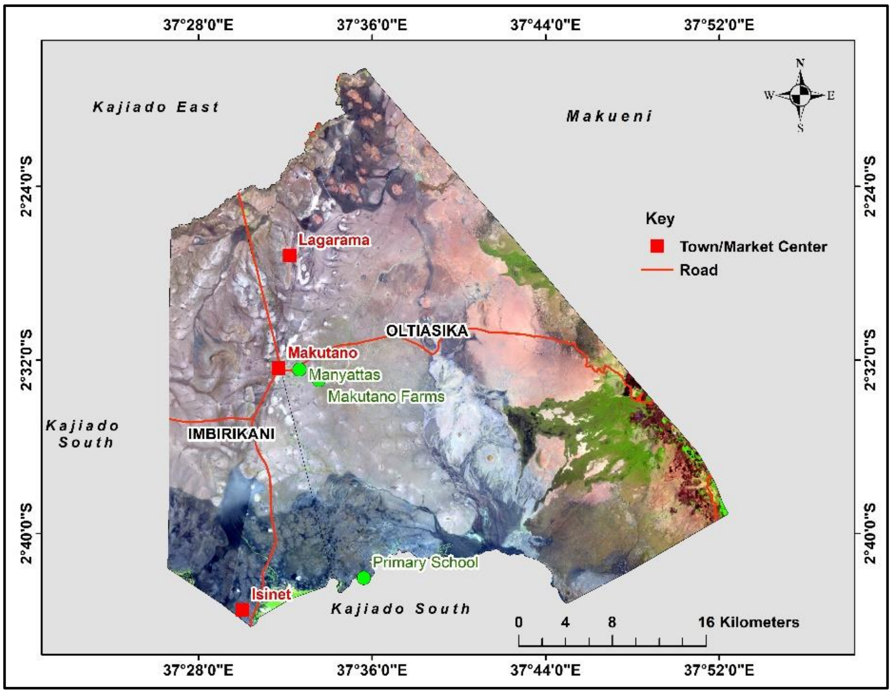

Plate 3. 7: Landsat 8 Imagery of Oltiasika showing Sampled Sites, December 2017

Most of the variable collected from the household survey were categorical in nature. Thus, the sample size was estimated using the formula proposed by Daniel (2018) shown in equation (1).

$$n = {Z^2pq}/{e^2} = (1.96^2 * 0.64 * 0.36)/0.05^2 = 354 \ldots\ldots\ldots (1)$$

Where n is the sample size, Z is the Z score corresponding with the desired level of confidence (95%), P is the estimated proportion in the population, $q = 1 - p$, e is the tolerable margin of error or precision of the estimate.

Qualitative data was obtained from 20 participants organized into 2 Focus Group Discussion (FGD)'s representing the main livelihood types and 8 in-depth Key

Informant Interview (KII). FGD and KII participants were selected with consultation with government technical workers in Loitoktok, local administrator and leaders of Mbirikani Group. Apart from gender consideration, selection of the participants was based on their knowledge of the subject under inquiry.

3.4.3 Sampling Procedures

A household was the union to analysis. In drawing the sample, a list of households of Oltiasika Division was obtained from the Executive Committee of Mbirikani Group Ranch to constitute a sampling frame. The actual households from which data was obtained were sampled in two stages. The first stage involved organizing a workshop for opinion leaders, where all villages were spatially plotted on a map. The villages were then stratified according to the dominant livelihood type with 70% representing pastoral villages. This ensured that subgroups of interest in the inquiry were included in the sample. The second stage involved allocating the sample size to each village using probability proportionate to size.

Households from which information was elicited were identified using the Ministry of Health's Expanded Programme for Immunization (EPI) approach outlined in Bostoen and Chalabi, (2006). A position near the centre of the village was estimated and a random direction chosen by spinning a pen. By walking outwards, a house was randomly chosen for inclusion in the sample followed by the one closest to it. This technique was appropriate because there was no sampling frame and a high rate of immigration experienced in the area.

3.5 Validity and Reliability

Interviews were conducted by three researcher assistants trained on how to ask questions an in the same manner. Before they were deployed they were trained to understand the data being sought to address the study objectives. The questions were translated into Maa language and the research assistant instructed to ask the questions and written in the instrument, and only allowed to clarify where necessary. Every day there was a debriefing session to share experiences and seek clarification on any issue. Information from the household interviews was triangulated from that obtained from the FGDs and KII to ensure internal validity and allow generalization of results.

3.6 Study Dependent and Independents variables

The study had two models and therefore two dependent/endogenous variables namely Normalized Difference Vegetation Index (NDVI) and Household Resilience. The respective independent/ exogenous variables were Standardized Precipitation Index (SPI) and a set of household's characteristics (Table 3.2).

Table 3. 2:Study Dependent and Independent Variables

Dependent/Endogenous variable	**Independent/Exogenous variables**		
	Climatic	Socio-demographic	Economic
NDVI	SPI		
Resilience	Adaptation	Age Household size Education level	Occupation Asset owned Leased land Net income Livelihood diversification Source of irrigation water

3.5 Data Collection

Quantitative data was collected as both secondary and primary data. Secondary data was collected from a review of published and grey literature available in government ministries, libraries and websites using various search engines. The documents included the county integrated development plan, population reports, and previous studies on drought, pastoralism and livelihood changes in Oltiasika area. The main literature was obtained through subscription to relevant academic research journals.

3.5.1 Collection of Rainfall Data

Rainfall data was downloaded from the global weather data Soil and Water Assessment Tool (SWAT) database at http://globalweather.tamu.edu. The database comprises daily Climate Forecast System Reanalysis (CFSR) on precipitation, wind, relative humidity and solar covering the period 1979 to 2014. Data for 2015 and 2016 were provided by the Kenya Meteorological Department (KMD). Fuka, *et al*. (2013) notes that CFSR dataset generated by the National Weather Service's NCEP Global Forecast System comprise precipitation and temperature for any land location in the world. Since there was no single weather station within the study area, rainfall data was extracted from Sultan Hamud Station No. 9237049 located on -2.654S, 37.5813E. Inference of this data was deemed appropriate as it falls within the same climatic zone as the study area.

3.5.2 Downloading of Normalized Difference Vegetation Index Data

The MODIS instrument provides high radiometric sensitivity (12 bit) in 36 spectral bands ranging in wavelength from 0.4 µm to 14.4 µm. NDVI is data was derived from the global MODIS Level-3 16-day VI products available both from the MODIS Terra (MOD13Q1) and Aqua (MYD13Q1) satellites at 250-m pixel size. HDF-EOS image file data are mainly obtained through the on-line LP DAAC Data Pool, which provides direct ftp access to all MODIS products (Vuolo, et al 2012). In 2011, the government of Kenya established a National Drought Management Authority (NDMA) to coordinate drought management within the country. To determine the drought status of a local scale in an objective, reproducible and cost efficient way, NDMA decided to use Earth Observation (EO) data. For near real-time (NRT) provision of EO data, the University of Natural Resources and Life Sciences (BOKU) developed and implemented an advanced filtering method for Moderate Resolution Imaging Spectroradiometer (MODIS) normalized difference vegetation index (NDVI) images for NDMA. The BOKU processing yields reliable drought indicators at county and sub-county levels for various aggregation times and livelihood zones. Pre-processed NDVI images were therefore obtained from the University website at http://ivfl-info.boku.ac.at/index.php/eo-data-processing/dataprocess-global. The images are a gridded level-3 data in approximately 250 m spatial resolution in Sinusoidal projections with a temporal resolution of 16 days (Klisch *et al*., 2015). The website provides global smooth and continuous (from 2000 - to present) Normalised Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) data.

The processing chain relies on MODIS Level-3 16-day composite Vegetation Indices (VI), which are standard MODIS products available at 250-m pixel size both from the Terra and Aqua satellites. MODIS Level-3 data are produced in tiles of 10 by 10 degrees and distributed in the Sinusoidal projection. The spatial and temporal Level-3 composites are calculated from the Level-2 daily surface reflectance swath data (MOD09 and MYD09 series) using the Constrained View angle - Maximum Value Composite (CV-MVC) compositing method. The combination of 16-day composites from both the Terra (MOD13 series) and Aqua (MYD13 series) satellites allows a temporal resolution of 8 days.

MODIS data was used because it is free, is more frequent and has higher spatial resolution compared to other data sets. Furthermore, MODIS NDVI does not suffer from the problem of data inconsistency from multiple sensors as for the other long-term NDVI datasets. Data from BOKU has already been corrected to remove the effects of solar angle and sensor errors. Studies such as those of Nemani *et al*. (2003) and Mao *et al*. (2012), have utilized this data set to monitor long-term vegetation activities. MODIS data were acquired by specifying the coverage using the bounding box coordinates (2.215S, 37.400E); (2.215S, 37.942E) and (2.773S, 37.400E), (2.773S, 37.942E). A gapless 16-day time series NDVI composite raster data for the period 1st January 2000 and 2nd July 2016 was used. The images were downloaded using file Zilla software then uploaded on ArcGIS 10.2.2 platform.

The image pre-processing involved image re-projecting to ensure that they were represented in a uniform coordinate system of the World Geodetic System (WGS 84). Statistics for the NDVI for each pixel were extracted to tables (Appendix 4) and the values reduced to acceptable level of between 0-1 by multiplying by a factor of 0.0001. MODIS data is useful in detection of climate and environmental change and the images from MODIS satellites generate information on drought conditions in an objective and reproducible matter (Gao et al., 2008).

3.5.3 Collection of Spatial Data

Accessing very high-resolution satellite data needed to map and derive land cover information in highly heterogeneous landscapes with smallholder agriculture is still a challenge. Freely available including Landsat and MODIS are too coarse and are limited when deriving land cover information (Nakalembe *et al.,* 2017). Hence, in this study, change detection maps of the study area were generated using Satellite images downloaded from Google Earth (Google, 2017) data set from https://www.google.com/earth/download/ with spatial resolution of less than 1m. Google Earth provides the latest high-resolution satellite imagery and is readily visualized with tools available in most popular image processing and GIS software such as ArcGIS, ENVI, and ERDAS IMAGINE. Because Google Earth desktop application has a data repository of processed satellite images acquired over time, it makes it possible to study land cover changes of a place on a temporal scale. Google earth images have also a high resolution that enables close look of the area under investigation (Shim, 2004). Spatial data was collected as per the schematic diagram shown in Figure 3.7.

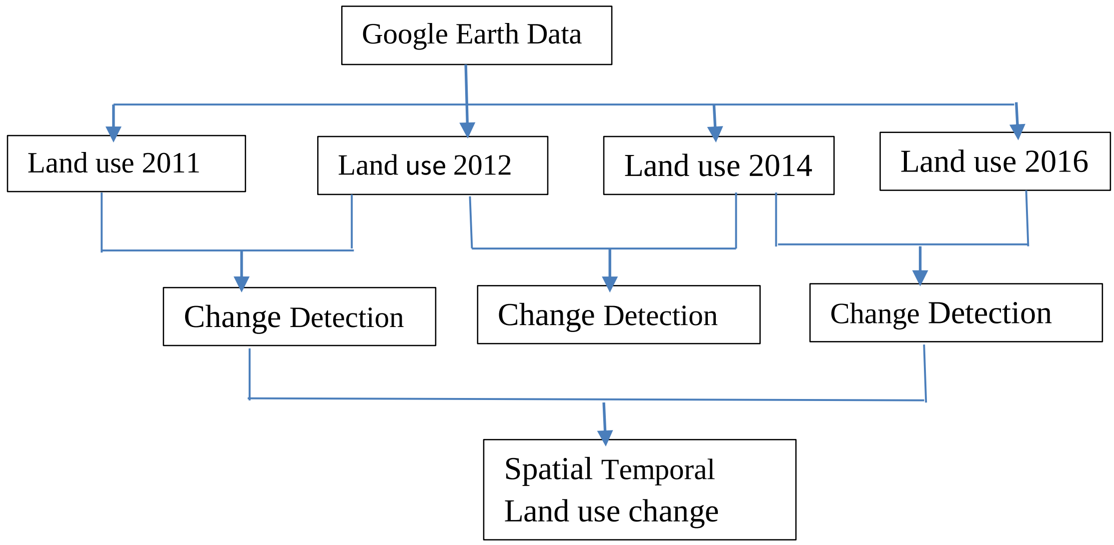

Figure 3. 1 : Schematic Diagram for Change Detection Analysis

The main disadvantage of Google Earth is that it does not allow the use of original multispectral band data and, therefore, does not have spectral signatures image classification using unsupervised or supervised techniques. Yet, since the spatial resolution is very high, it is possible to visually see on the image key features and on-screen digitizing in GIS can easily be performed to detect any changes (Malarvizhi *et al.*, 2016;). The initial observation helped sample five sites for purposes of observing changes that have occurred over time. The sites are Makunato Centre used to assess urban development, Makutano farms for detecting changes in land under cultivation, a Manyatta in the immediate south of Makutano, permanent structures and a school.

3.5.4 Collection of socio-economic data

Social economic data entailed qualitative as well as quantitative data. Quantitative data was collected through a household survey, while, qualitative data were collected through Focused Group Discussions (FGDs), and Key Informant Interviews (KII). A household survey was conducted between January and February 2015. A semi-structured questionnaire was used to collect data on respondents' experience on drought, its impacts and adaptation strategies. This method when administered face-to-face is known to have a high response rate as it enables illiterate respondents to participate and allows clarification of ambiguity (Pero & Crowe, 1996).

A semi-structured questionnaire was designed following the Bradburn, et al. (2004). Accordingly, the questionnaire was organized into various sections for ease of administration (Appendix 1). The RA moved in through the area on motorbike, explained the purpose of the survey and sought respondents consent in participating in the survey. They posed questions on a range of issues including, demographic and social economic characteristics, livelihood systems, perceived climate change and impacts, adaptation strategies and household food resilience (food availability). On average, the questionnaire took about 50 minutes. All sampled households were geo-referenced using a GPS instrument (Plate 3.1) during field survey.

Prior to the actual data collection, a reconnaissance survey was undertaken in September 2014 by the researcher to familiarise with the study area and establish contacts with the local chief and officials of the Group Ranch. During this period, necessary, logistical arrangements were made and potential research assistants identified. Thereafter, the questionnaire was pre-tested in Lengesim Group Ranch, adjacent to Mbirikani to enhance clarity, reliability and robustness.

Throughout the entire survey period, the researcher stayed among the community to observe their behaviour under normal conditions and gain greater insights on livelihood practices.

FGDs were conducted following Boddy (2005) and were meant to clarify information emerging from the survey and elicit deep-seated information on issues not captured by the questionnaire. Two FGDs were conducted, the first one with 11 participants whose main livelihood was crop farming and business, while the second had 10 participants, mainly pastoralists. Both meetings were held at Makutano Centre as most household heads spend much of their time in the centres as a way of updating themselves on the current affairs, and each lasted about two hours. At the end of each FGD session, participants were compensated an amount equivalent to what they would be paid for a two-hour contract working. In order to ensure an integrative perspective of change, participants were carefully selected taking into account factors such as age, gender, economic status and primary occupation (Chambers, 1983).

Prior to the FGD sessions, participants agreed on a set of rules to guide the discussions and informed consent was sought to enable audio recording of the proceeding. Local Maa language was used in the discussions since this is the primary language spoken by inhabitants of Oltiasika area. The research assistants helped with the facilitation and translation of the discussions to Swahili and English. Transcription of the recorded discussions ensured accurate verbatim documentation of the discussions and allowed the interviewer more time to moderate the discussions and probe the responses instead of concentrating on taking notes. The discussions covered an array of issues as shown in Appendix 2. Discussions on livelihood diversification focused on 2009, when the area experienced the worst drought in recent history. Moreover, 2009 was six years from the time of the meeting, a period for which community members can accurately recollect changes in livelihood system.

Eight Key Informant Interviews (KIIs) were also conducted with people thought to have appreciable knowledge on climate change and livelihood in Mbirikani. These included Mbirikani Group Ranch officials, livestock extension officer and local administrative chief. The purpose of information emanating from in-depth interview was to triangulate that from household survey and in the FGDs. The interview guide for the KII mainly focused on views on drought impacts, traditional and emerging livelihood strategies, the participation of local people and general opinion on the future of pastoral livelihood under a changing climate (see appendix 2). It entailed asking questions, listening to and recording the answers, and then posing additional questions to clarify or expand on an issue. Respondents were also encouraged to express their views in own words.

3.5.5 Selection and Training of research assistants

This study employed the services of three research assistants (RAs) in data collection. The RAs were selected based on gender, education and ability to communicate fluently in English, Kiswahili and Maa (dominant language in the study area). All RAs had a college level training to ensure they grasped the proposal and could acquire skills during the training on questionnaire administration. During the training, the RAs were first taken through the entire proposal to gain a good understanding of the issues being investigated, before trained on how to elicit and record data on the questionnaire, as well as on the use of the use of recording instruments. Using RAs was meant to increase the response rate, help in identifying villages and encourage participation of respondents who would not speak in either English or Swahili.

3.5.6 Data Management and Ethical Considerations

Before embarking on the fieldwork a research permit was obtained from the National Commission for Science, Technology and Innovation (NACOSTI) as required under the Science, Technology and Innovation Act, 2013. A copy of the permit was deposited at Kajiado County Government offices. Throughout the data collection process, informed consent from the respondents was always obtained before administering the questionnaire, and respondents assured of the confidentiality of their response.

3.6 Data Analysis

3.6.1 Time series regressions of drought and vegetation indices in Oltiasika Area

Analysis of the relationship between drought and vegetation conditions was performed in three stages; computation of the Standardized Precipitation Index (SPI), derivation of the Normalized Difference Vegetation Index (NDVI) and estimation of the relationship between these two variables.

Computation of SPI involved fitting monthly rainfall for the study area into a gamma distribution function (Thom, 1966) defined as:

$$f(x) = \frac{\left(x/\beta\right)^{\alpha-1} e^{-x/\beta}}{\beta\Gamma(\alpha)} \text{ for } x, \alpha, \beta > 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

$\Gamma(\alpha) = \int_0^\infty e^{-t} t^{\alpha-1}\, dt$ is the gamma function.

Where, x is the rainfall amount, α and β are shape and scale parameters respectively which are estimated using maximum likelihood method (Wilks, 2006).

The parameters were estimated by calculating an intermediate value U as shown in equation (3).

$$U = \ln(\bar{x}) - \frac{\sum \ln(x_i)}{n} \dots\dots\dots \text{(3)}$$

$$\hat{\alpha} = \frac{1}{4U}\left(1 + \sqrt{1 + \frac{4U}{3}}\right) \dots\dots\dots \text{(4)}$$

$$\hat{\beta} = \frac{\bar{x}}{\hat{\alpha}} \dots\dots\dots \text{(5)}$$

Where, U is a measure of skewness given as:

$$U = \ln(\bar{x}) - \frac{\sum \ln(x)}{n} \dots\dots\dots \text{(6)}$$

n = number of rainfall observations.

x_i is represent all non-zero values in the rainfall, and $\bar{x}$ is the arithmetic mean of all non-zero value. The resulting α and β are used to determine the cumulative probability of a rainfall event for given month and time scale using the function as shown in equation (7):

$$G(x) = \frac{\int_0^x x^{\hat{\alpha}-1} e^{-x/\hat{\beta}} dx}{\hat{\beta}\Gamma(\hat{\alpha})} \dots\dots\dots \text{(7)}$$

Since the gamma function is undefined at x=0, the final cumulative probability becomes:

$$Hg(x) = qg + (1 - qg)G(x) \dots\dots\dots \text{(8)}$$

qg is the empirical probability of a zero, and can be estimated by the ratio between the number of observations N and the number of zeros (n) within the sample. $G(x)$ is determined using tables of incomplete gamma function (Thom,1966). The resulting cumulative distribution $Hg(x)$ is then transformed to a normal random variable with mean zero and stand deviation one to obtain SPI.

Once the drought measure is defined, the thresholds on drought parameters were defined to enable its characterization (Sheffield and Wood, 2007). In this study drought were categorized using thresholds established by the world Meteorological Organization (WMO, 2012) as shown in Table 3.3.

The sum of absolute values for SPI for a drought event was used to define the magnitude. The main advantage of SPI is that it can be computed across different timescales to monitor various drought parameters (Du *et al*., 2013).

Table 3. 3: Drought Classification using Standardized Precipitation Index

Range of SPI Value	Drought category	Colour
>2.00	Extreme wet	
1.50 to 1.99	very wet	
1.00 to 1.49	Moderate wet	
-0.99 to 0.99	Near normal	
-1.00 to -1.49	Mild drought	
-1.50 to -1.99	Severe drought	
<-2.00	Extreme drought	

Source: WMO, (2012)

The NDVI was computed using formula:

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} - \rho_{RED}} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (9)$$

Where: $\rho_{NIR}$and $\rho_{RED}$is spectral reflectance in the NIR infrared channel and red-channel respectively of the satellite senor (Tucker, 1979).

The effect of drought on biophysical system was analysed using changes in vegetation conditions by use of NDVI. Time series data sets for SPI and NDVI were analysed to examine the impacts of drought on vegetation changes using an autoregressive model of the form shown in equation (10) as described by (Green, 2002).

$$\mathrm{NDVI_t} = \beta_0 + \beta_1 \mathrm{SPI_t} + \mathrm{AR}(1) + \mathrm{AR}(2) + \mu_t \dots \dots \dots \dots \dots \dots \dots \dots (10)$$

$$\mu_t = \rho\mu_{t-1} + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (11)$$

Where, $NDVI_t$ is the current NDVI, $AR(1)$ is NDVI for the past one month, AR (2) is the NDVI for the past two months $SPI_t$is current standardized precipitation β_0 & β_1 are coefficients of the model, while $\varepsilon_t$is the error term.

The number of lags was identified by selecting the model with the lowest Akaine Information Criterion (AIC). One of the assumptions underlying Ordinary Least Square (OLS) is that the errors that have got no serial correlation; a condition violated in time series data as it is often prone to cyclic behaviour. Breusch-Pagan-Godfrey test was used to test for serial correlation between the model variables. Estimation of the model was performed in EVIEWS statistical software.

3.6.2 Change Detection in Oltiasika Area

In analysing spatial data, Google Earth application was preinstalled in a desktop and made the default application for reading and writing kml file types. A kml file was prepared in ArcMap 10.5 by converting Oltiasika.shp to Oltiasika.kml using the data conversion tool before being opened in Google Earth to make observations. Using a Time slider tool and panning through the image, to observe changes that have occurred in the area between 2009 and 2016. These changes were recorded using the Save Image tool and imported to ArcMap for Geo-referencing and digitizing to generate vector data. Sites with greatest observable changes and having data for more than one period were selected. The coverage of the sites was dictated by the spatial resolution, which allowed the changes to be clearly detected on the images; large coverage resulted in loss of vital information. Annual observed changes on the images were recorded down to generate trends in variables in interests.

To allow classification of google earth images, ground-truthing observations as proposed by Thomas and Ayuk (2010) was carried out along a transect line cutting across the study towards the Chyulu hills. A hand held Global Positioning System (GPS) was used in the ground truthing exercise to ensure that features on ground are in their correct planimetric position on the images. Six land use classes; rangeland, bare ground, wetlands, built-up, cultivated land, riverine vegetation were delineated as the major land use cover types.

3.6.3 Ordered Logistic Regression of Livelihood Diversification and Household Resilience

This objective was analysed using survey data. Prior to data analysis, the questionnaires were checked for completeness and those with no response removed from further analysis. The remaining questionnaires were coded, entered into spreadsheet, and cleaned up before subjecting them to statistical analysis. Descriptive statistics using cross-tabulation; measures of central tendency of mode, median and mean; standard deviation, minimum, maximum, percentages, and percentiles were used to summarize data on the study variables. The results were presented in maps, tables, and charts.

Analysis of qualitative data entailed systematically entering interview notes into data capture spread sheets — organized by key topics and questions - along with key identifying information, such as the name of the interviewee, the type of stakeholder group they represented, and their contact. Audio-recorded data were first transcribed and organized into emerging themes from which inferences were drawn. Data were coded and indexed, and emerging themes were grouped and conclusions drawn. Notes taken during field work were also read repeatedly to identify common themes upon which conclusions were drawn.

The effect of livelihood diversification on household resilience was analysed in two steps. A household livelihood diversification was first computed using the Herfindahl-Hirschman index (HHD) according to (Ellis, 2000). HHI is commonly used to measure the market concentration of a firm in studies on biodiversity and financial economic (Ellis, 2000). HHD is computed using the formula:

$$HHD_i = \sum_{i=1}^{N} a_i^2 \qquad \text{.......12}$$

Where *a* is the share of activity *i* in the total market.

While HHD is a measure of concentration; its inverse measures degree of market diversification. This approach has been extended to measure income diversification in rural households in Tanzania (Ellis, 2000), India (Anderson and Deshingkar, 2005) and Ghana (Abukari, 2014).

IHHD is expressed as:

$$IHHD_i = \left[\frac{1}{\sum a_j^2}\right]_i \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (13)$$

Where a_j= proportion of each livelihood activity j to household i's overall income. The maximum value it can take correspond to the number of different income sources which can be attained if total income is distributed equally between each source, while the minimum value is 1, which is attained when all income is derived from a single source (Ellis, 2000).

Household resilience to drought measured the capacity of a household to cope with drought. It was defined as the number of months in a year when households do not have adequate food to meet the requirements of all members. The number of months categorized into four and assigned arbitrary codes: 0=0 months, 1=1-3 months, 2=4 months and 3=more than four months. Note that the number of months and household resilience are inversely related, meaning that the fewer the number of months the higher the household drought resilience and vice versa.

Since the dependent variable was discrete the relationship was analysed using a general ordered logistic model (Khorashadi *et al.,* 2005). The model combines the independent variables to estimate the probability that a particular event will occur. It treats the variable (Y) as if it were measured on an ordinal scale although the ordinal scale represents crude measurement of an underlying interval scale (Y^*) . Following Cameron and Trivedi (2005), the model can be specified as:

$$y_i{}^* = x_i'\beta + \mu_i \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (14)$$

As y^* crosses a series on increasing unknown thresholds, the ordering of alternatives moves up.

For an m – alternative ordered model,

$$y_i = j \text{ if } \alpha_{j-1} < y_i^* \leq \alpha_j \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (15)$$

Where$\alpha_0 = -\infty$ and $\alpha_m = \infty$. Then the probability that observation i will select alternative $j$is given by:

$$\mathrm{P_{ij}} = \Pr[\mathrm{y_i} = \mathrm{j}] = \Pr[\alpha_{\mathrm{j}-1} < \mathrm{y_i^*} \leq \alpha_{\mathrm{j}}] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (16)$$

$$=\Pr[\alpha_{\mathrm{j}-1} < \mathrm{x_i'}\beta + \mu_{\mathrm{i}} \leq \alpha_{\mathrm{j}}]$$

$$=\Pr[\alpha_{\mathrm{j}-1} - \mathrm{x_i'}\beta < \mu_{\mathrm{i}} \leq \alpha_{\mathrm{j}} - \mathrm{x_i'}\beta]$$

$$=\mathrm{F}(\alpha_{\mathrm{j}} - \mathrm{x_i'}\beta) - \mathrm{F}(\alpha_{\mathrm{j}-1} - \mathrm{x_i'}\beta)$$

Where F is the Cumulative Density Function (CDF) μ is logistic distributed with:

$$\mathrm{F(z)} = \frac{\mathrm{e^z}}{(1 + \mathrm{e^z})} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (17)$$

The marginal effect, which gives the probability of an independent observation falling within a category of the dependent variable, is given by:

$$\partial p_{ij} \big/ \partial x_{ri} = \{F(\alpha_{j-1} - x_i'\beta) - F(\alpha_j - x_i'\beta)\}\beta_r \ldots\ldots\ldots.\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (18)$$

Based on the foregone analytical framework, the qualitative analysis for objective three was performed using equation 19.

$$\mathrm{RESIL} = \alpha\mathrm{IHHD} + \beta\mathrm{X} + \varepsilon \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots....(19)$$

Where, RESIL is a proxy measure of household resilience defined by the number of months the household has adequate food, IHHD, is the degree of household diversification, X is time-invariant household characteristics and ε is a stochastic error term. Socio-economic characteristics such as age, gender, education level, household size, and marital status influence rural farmers’ response to climate variability and extremes (IPCC, 2014), but they vary between individuals, societies, countries and regions (Eriksen *et al*., 2011). The variables used to assess the social dimensions of the study are presented in Table 3.4.

Table 3. 4: Definition and Measurement of Ordered Logit Model Variables

Variable	Description	Measurement	Expected sign
RESIL	A dependent variable and proxy for household resilience. Defined by number of months a household does not have adequate food to meet the needs of all household members	Categorical variable Strong (0) =0 months Moderate (1) =1-3 months Low (2) =4 months Very Low (3) = more than 4 months	
AGE	age in years of household head	A continuous variable	+ve
HHSZE	total number of household members	Continuous variable	+ve
EDUL	The number of years in formal education by the household head	Categorical variable 0=No formal education; 1= primary, 2=secondary, 3=tertiary	-ve
OCCUP	The main occupation of the household head	Categorical variable 0= livestock;1= crop farming; 2= business; 3=salaried employment	Indeterminate
IHHD	A measure of the extent of household livelihood diversification	An index ranging between 0-1 as defined in section 3.7.1	-ve
TASSET	Sum of all assets owned by a household	Continuous variable	-ve
LEASE1	Whether household leases their primary land where the homestead is located	A binary variable 0=Yes; 1= No	Indeterminate
LEASE2	Whether household leases land within Oltiasika but not the primary land	A binary variable 0=Yes; 1= No	-ve
CADPT	Whether a household has taken any measures to adapt to climate change	A binary variable takes 0=if household has adapted, 1 otherwise	-ve
IRSURCE	The source of water used by crop farmers for irrigation activities	Categorical variable 0=swamp; 1=dam; 2=pipeline	Indeterminate
NTCOME	Household net non-farm income	Continuous variable	-ve

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This study set out to investigate livelihood diversification in response to drought among pastoral community of Oltiasika area, Kajiado County. It pursued three objectives namely to assess the relationship between drought and vegetation conditions in Oltiasika area, to assess livelihood diversification among pastoral communities, and to analyse the effect of livelihood diversification on household drought resilience. This chapter presents the results of the analysis carried out in the previous chapter and comprises three sections. The first section shows the results of the assessment of drought patterns and its effect on vegetation conditions. The second section gives the results of the livelihood diversification among pastoral communities in Oltiasika area, while the third section presents results of the empirical relationship between livelihood diversification and household resilience.

4.2 The Relationship Between Drought and Vegetation Conditions in Oltiasika Area

The results under this section relate to objective one of the study, which aimed to establish the relationship between drought and vegetation conditions. The gist of the objective was to quantify drought episodes experienced in Oltiasika area and assess their impact on pasture conditions, and therefore on pastoral livelihood. It also aimed at providing insights on how pasture responds to variations in drought. Drought was measured using the Standardized Precipitation Index (SPI). Changes in vegetation conditions using Normalized Difference Vegetation Index (NDVI) were computed to show trends in pasture conditions as explained in section 3.5.3. The relationship between the two variables was analysed using simple regression analysis as shown in equation (13).

After presenting descriptive statistics for the rainfall data used to compute the SPI, the section proceeds to present the SPI before that of NDVI patterns. NDVI was described in statistical terms as well as by MODIS images. The section concludes with the results of the regression analysis between SPI and NDVI.

4.2.1 Statistical Description of Rainfall Data used to Compute Drought Index

The rainfall data used to compute the Standardized Precipitation Index (SPI) contained a record of 379 monthly rainfall between the period January 1983 and September 2016 covering a total of 453 months (Figure 4.2). Since 1979 the trend of monthly rainfall (mm) for the area show high variability but increasing trend with R^2 (0.07) (Figure 4.1).

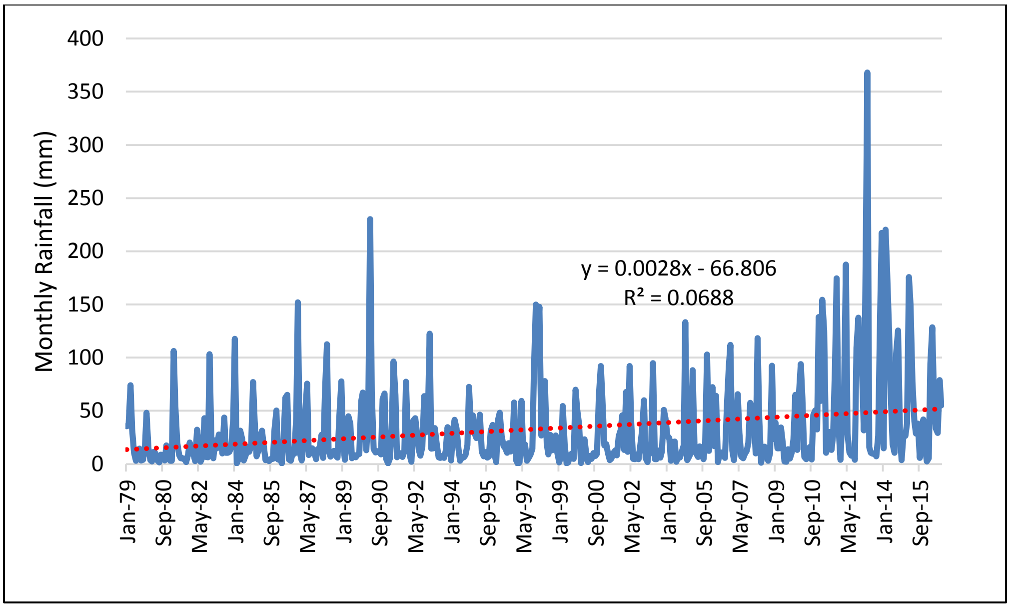

Figure 4. 1: Precipitation in Oltiasika using data from Sultan Hamud Station No 9237049

The total rainfall data for the period had a monthly mean of 32.64 mm and a standard deviation of 42.26. The minimum value was zero while the maximum 368.078 mm. The value of the probability (0) show that the rainfall changes in the area is significant. As expected of an ASAL area, monthly rainfall varies greatly from the mean with only five months; January, March, April, November and December recording averages above the 32.93 mm monthly mean. April is the wettest month with monthly average of 67.04 mm followed by November (63.34 mm). The period between June and October receives very low rainfall with September receiving the lowest rainfall (6.10 mm) (Figure 4. 2).

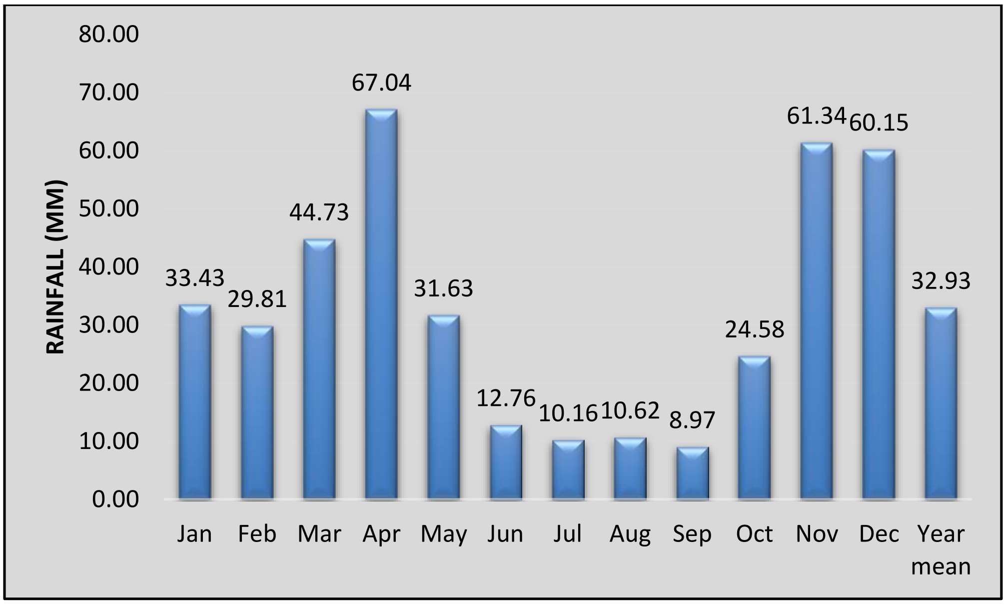

Figure 4. 2: Mean Monthly Rainfall for Oltiasika Area

The area experiences two main rain seasons: the long rains (*Nkokua* in Maa language) corresponding to the months of November-December-January (NDJ) and the short rains (*Oltumure*t) falling in March-April (MA). The two seasons have average monthly rainfall above the year mean. Although the area experienced overall increase in rainfall, there were variations across seasons (Figure 4.3) with NDJ showing increasing rainfall, while MA had a decline in average rainfall, an indication of poor rainfall distribution.

4.2.2 Standardized Precipitation Index for Oltiasika Area

The SPI derived from rainfall data from Sultan Hamud Station by fitting the monthly rainfall into a gamma distribution function as already explained in section 3.6.1. The computation yielded corresponding SPI values shown in (Appendix 6). The SPI values had these statistical properties: mean -0.25, median -0.35, maximum 3.26, minimum -4.64, and a standard deviation of 1.321. The 10 months with the lowest SPI values were March 1986 (-2.34), February 1991(-2.49), May 1999 (-2.39), February 1984 (-

2.37), January 2000 (-2.191), May 2008 (-2.11), January 1999 (-2.06), June 1999 (-2.00), March 1997 (-1.99) and February 2003 (-1.94). The 10 months with the highest SPI were April 2013 (4.68), April 1990 (3.46), February 2014 (3.36), December 2013 (3.32), March 2013 (3.12), April 2012 (3,00), March 2014 (2.90), November 2011 (2.85), March 2011 (2.56) and December 1986 (2.57).

Over the period 1983 to 2014, the SPI for the weather station exhibited a cyclic behaviour with peaks and troughs (Figure 4.3). Drought is highly variable in the area with wet periods followed by dry spells.

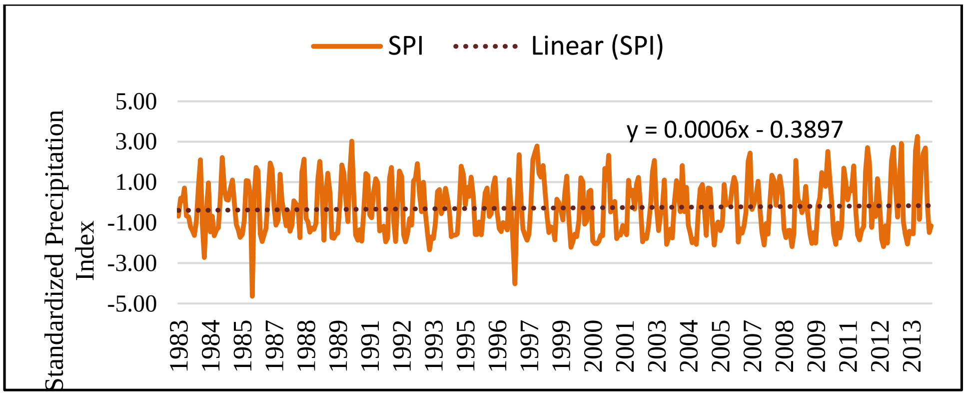

Figure 4. 3: Standardized Precipitation Index for Oltiasika Area, 1983-2014

The coefficient of the SPI trend line for the areas was small but positive (0.0006), pointing to increasing drought conditions. Various drought categories for the area were identified using World Metrological Organization (WMO) classification. In the period 1984-2013, the area experienced a total of 145 drought events (38.98%). Severe droughts were the most common (69 months) followed by mild drought (57 months) while extreme drought occurred in 19 months. The distribution of droughts for the entire period is shown in Appendix (7) while that of extreme drought is summarized in Table 4.1.

From these results, prior to 1999, extreme drought (with SPI value less than -2) occurred on average every 3.75 years between 1984 - 1999, but increased in frequency to on average every 1.4 years in subsequent years, a reduction in the drought cycle. Three years 2000, 2004, 2009 and 2012 had more than one month of extreme drought.

Between 1984 – 2013 majority of extreme droughts occurred in July (8), followed by June and September (4), February (2), and January (1).

Table 4. 1: Distribution of Extreme Drought Months in Oltiasika Area

Year	No. of drought events	Months
1984	1	February
1986	1	February
1993	1	July
1997	1	January
1999	1	June
2000	2	June, July
2003	1	June
2004	2	July, September
2005	1	June
2007	1	July
2008	1	September
2009	2	July, September
2010	1	July
2012	2	July, September
2013	1	July
2014	3	
2015	2	
2016	3	

Between 1984-1989, the number of occurrence of extreme months were two but decreased to one in the next five years before increasing to two in subsequent period. Between the period 1999-2004 and 2004-2009, the number of extreme drought months increased dramatically to five. This trend persisted in the area as four extreme drought episodes were recorded in the final four years.

To gain further insights on drought characteristics in the study area, SPI values were categorized and then sorted to identify the 10 greatest magnitude and 10 most severe drought years (Table 4.2). As explained in section 3.6.2, the magnitude of drought is computed by taking the sum of absolute values for SPI for a drought event, and measures the persistence of drought. The categorisation of drought condition in the area is presented in Appendix 7.

Table 4. 2: Magnitude and Severity of Drought in Oltiasika using Standardized Precipitation Index

Year	Drought Magnitude	Year	Drought Severity
1986	-2.80	1997	-2.01
1984	-2.72	1986	-1.99
2004	-2.07	1992	-1.93
1997	-2.01	1984	-1.92
2009	-2.01	1989	-1.87
2012	-2.00	2000	-1.86
1992	-1.93	1999	-1.85
1990	-1.91	2012	-1.78
1989	-1.87	2009	-1.76
1998	-1.86	1988	-1.73

From the table, all years except for 2000 and 1988 experienced a drought with both high magnitude and severity, years with prolonged drought tend to experience severe drought as well.

The drought analysis shows that during the period 1983-2014, the area recorded a total of 145 droughts of different categories, 19 of which were extreme. These statistics mean that the average frequency of drought in Oltiasika is 2.6 years, but became more frequent between 2003 and 2013, with an extreme drought every year except for 2006 and 2011. Extreme droughts occurred in 1984, 1986, 1993, 1997, 1999, 2000, 2003, 2004, 2005, 2007, 2008, 2009, 2010, 2012, and 2013. This results agreed with those of Mutsotso, Sichangi, & Makokha (2018) who identified drought years in the entire country as 1987, 1998, 2000, 2001, 2005, 2006, 2008, 2009, 2010, 2011 and 2015, although they failed to categorize the type of drought. Zwaagstra et al. (2010) evaluated response to the 2009 drought and found that while the interventions implemented were consistent with what was in the contingency plans, the quality and timing of their implementation were often not consistent.

4.2.3 Changes in Vegetation condition in Oltiasika Area

MODIS Satellite images were used to derive NDVI conditions for the study area for the period January 2000 to July 2014. The data had a total of 175 months with a mean of 0.337 and a standard deviation of 0.095. The minimum value was 0.193 (September 2004) while the maximum was 0.620 (December 2006) (Plate 4.1 & 4.2). Since NDVI is an index ranging between 0-1, a value of 0.5 represents normal vegetation greenness. Values below 0.5 represent depressed vegetation, while those greater than 0.5 show enhanced vegetation. Of the total number of months, only 13 had NDVI above the average. These are April 2006 (0.501), January 2007 (0.506), March 2006 (0.513), April 2013 (0.515), April 2012 (0.534), March 2008 (0.541), November 2011(0.551), March 2010 (0.552), November 2000 (0.554), November 2002 (0.564), December 2000 (0.566), November 2006 (0.574), and December 2006 (0.620). As expected the NDVI values correspond to the rainfall season of the Oltiasika with six of the above average months corresponding to the first rainfall season of MA and the remaining seven to the second rain season of NDJ.

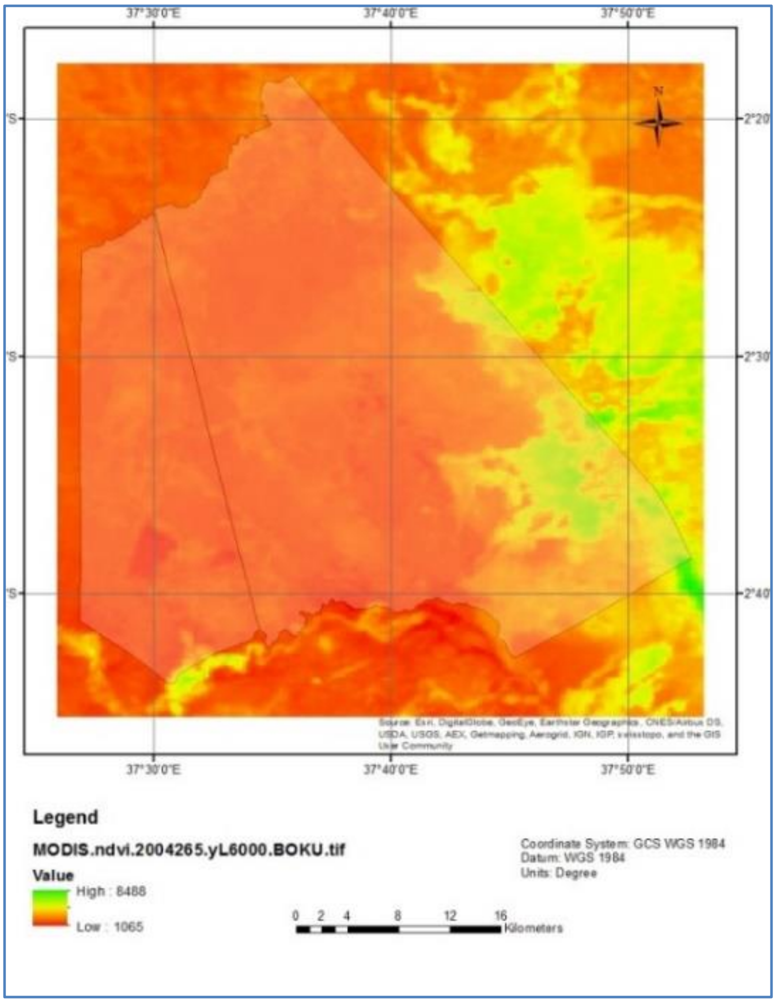

Plate 4. 1: Normalized Difference Vegetation Index for Oltiasika, September 2004

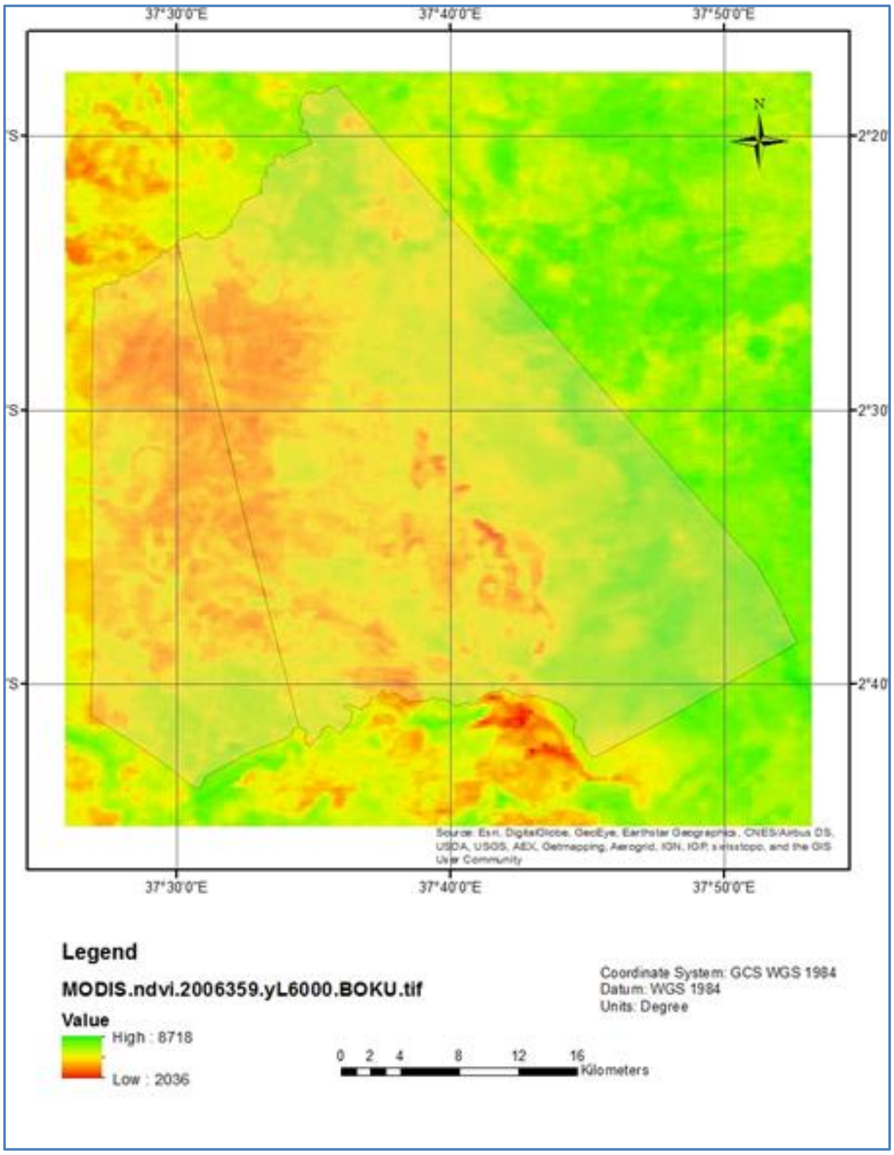

Plate 4. 2: Normalized Difference Vegetation Index for Oliasika, December 2006

Prior to 2009, 16 droughts were identified compared with 13 in the current study area. The findings show high variation in drought occurrence between the two study areas with only five years being similar. An important observation from the SPI analysis is the reduction in the drought cycle from an average of 3.75 per year prior the period 1999, to 1.4 years in the years after. Years with multiple extreme drought months seem to be concentrated in the period after 1999. The results show that the pattern of drought in the area has changed in terms of both frequency and intensity. According to the images, the 2004 drought affected the entire area with only a few sections of Chyulu Hills remaining green.

In order to examine the effect of altitude on vegetation condition, NDVI for a latitudinal transect was plotted across the study area (Figure 4.6). A transect was taken from the western direction to Chyulu Hills through Makutano market. The NDVI values increased gradually from 0.284 to 0.850 at Chyulu Hills with some interruptions at the central part where the values declined to 0.242 to -0.90.

The increasing trend as one moves to the hills was mostly attributed to the fact that the vegetation of Chyulu Hills have different characteristics and structure since they fall on lava forested area and is under a different management regime by the Kenya Wildlife Service. The Chyulu Hills was gazetted by the Kenya Wildlife Service in 1983 as a protected area, a move that limited the capacity of the pastoral communities to cope with drought. Information from respondents interviewed during the study complained that the gazettement denied them a critical dry season grazing area within their locality. Other dry season grazing options such as wetlands and riparian area have been converted to farmland, further exposing the community to drought risks.

Overall, the area has become drier as indicated by declining trend in the average annual NDVI values (Figure 4.4). The two driest years were 2009 (NDVI= 0.265) and 2005 (0.290), while the two most green years were 2000 (0.364) and 2006 (0.381), although in both years the annual average NDVI were below the 0.5 threshold.

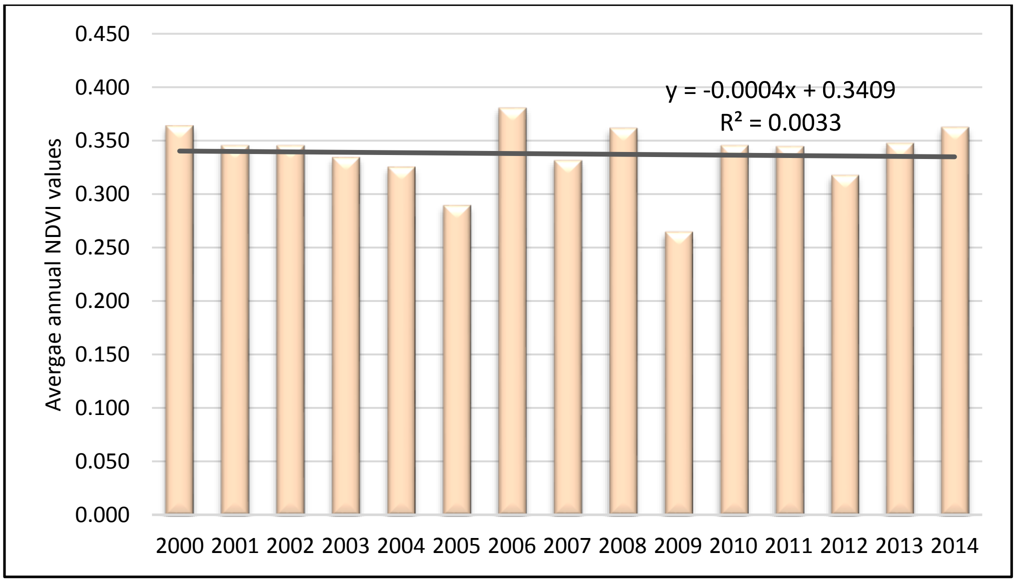

Figure 4. 4: Average Annual Normalized Difference Vegetation Index for Oltiasika Area

This enabled pastoralist to access diverse pasture and water resources within the Chyulu-ecosystem and beyond to ensure the survival and reproduction of their livestock (Little and Mcpeak, 2015). Considering that drought effects are not uniform but reduce as one moves towards the Chuyu Hills, thus made the hills an important dry season grazing area. The gazettement of the hills as a national park limited pastoral access to pasture and resulted in conflicts between communities and Kenya Wildlife Service. The policy to create a national park therefore increased community vulnerability as it reduced their coping space.

In order to examine the frequency of NDVI fluctuation, the NDVI series for 2000 and 2014 were plotted in a graph (Figure 4.5).

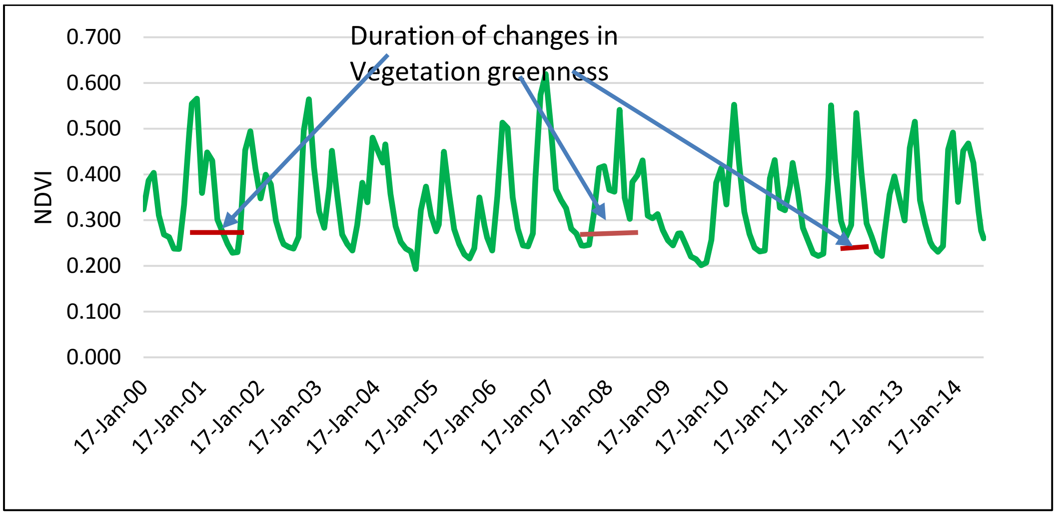

Figure 4. 5: Variation of Normalized Difference Vegetation Index in Oltiasika Area

From the graph, the duration of NDVI fluctuations appear to have decreased overtime showing similar trends as SPI. Another important observation is that since 2007, the maximum NDVI value has been declining, an indication of an area becoming drier. A study by Opole (2013) found that Kajiado area had experienced fourteen years of below average forage cover and nine years of above average cover. The longest period during which suppressed forage were recorded were; 1982 – 1984, 1991 – 1994 and 2002-2004. A single notable year, which saw vegetation sinking to its lowest, was in 2000 in which an average NDVI value of 0.2524 was registered. On the other hand, the area faced a long (three-year) period of above average forage cover from 1988 to 1990.

NDVI seasonal variations for the MODIS data were plotted in Figure 4.6. The results show that the whereas the NDJ values were generally higher than those of MA in the period before 2006, this situation was interchanged in the years thereafter. MA season is getting greener while NDJ season is getting drier as evidenced by their respective trend lines.

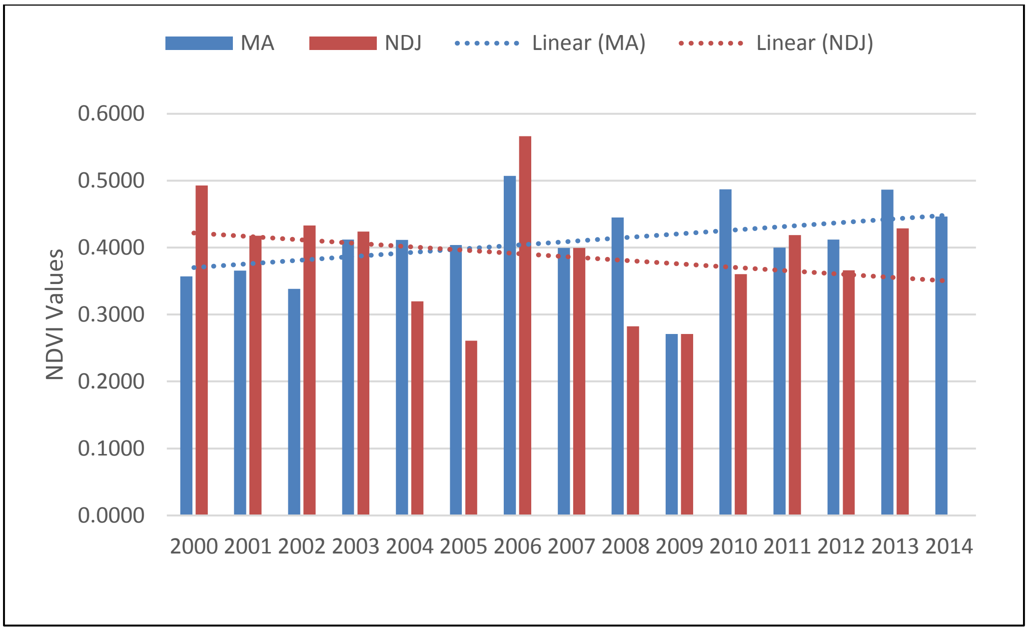

Figure 4. 6: Seasonal Normalized Difference Index for Oltiasika Area

The results present here so far show some relationship between SPI and NDVI in Oltiasika, which has been investigated further by use of statistical methods in the section that follow.

4.2.4 Results of the Auto Regression Analysis between Normalized Difference Vegetation Index and Standardized Precipitation Index

This section presents the statistical relationship between NDVI and SPI to enable the determination of the strength of the between vegetation greenness and drought conditions, and to establish the vegetation responds time to changes in precipitation. These results are based on a time series regression analysis specified in equation 13. Since NDVI data for vegetation was only available from 2000, corresponding SPI data was used in the equation. Prior to estimating the model NDVI and SPI, values were first plotted as shown in Figure 4.7 to show the relationship between the two variables. The graph shows that the two variables exhibited similar behaviour throughout the period between 2000 and 2014; when SPI declined NDVI declines and verse versa. This meant that the variables could be subjected to statistical tests to establish the strength of their relationship.

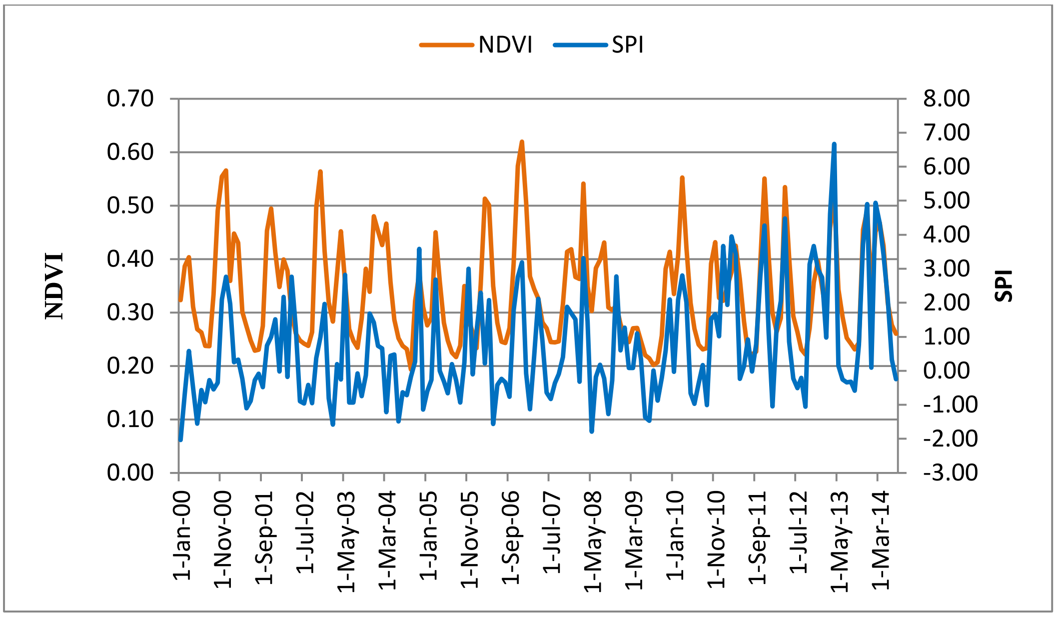

Figure 4. 7: Relationship between Normalized Difference Vegetation Index and Standardized Precipitation Index, Oltiasika Area

Monthly NVDI values (Appendix 9) and their corresponding SPI values (Appendix 6) were respectively entered in the equation as endogenous and exogenous variables. The first regression analysis between the two variables yielded the results shown in Table 4.3.

Table 4. 3: Regression Analysis of Normalized Difference Vegetation Index and Standardized Precipitation Index for Oltiasika Area

	variable	Coef.	Std. error	t-Statistic	Prob.
	C	0.349	0.005	66.514	0.000
	SPI	0.048	0.003	12.929	0.000
R-squared		0.491	Mean dependent var		0.337
Adjusted R^2		0.488	S.D. dependent var		0.095
Prob (F-statistic)		0.000			

Although the model had a low R^2 value (49.12 %), the corresponding F-statistic indicates that the model is highly significant. This means that SPI can explain NDVI in the study area. Since the variables contain time series data and the regressors not strictly exogenous, testing for Serial Correlation was performed using Breusch-Godfrey (Table 4.4). This test had a P-value of 0.0000, less than 5%, an indication that the model suffers the problem of serial correlation. This suggests that the regression analysis is not the Best Least Unbiased Estimate (BLUE) and that the standard errors and test statistics are no longer valid, even asymptotically. This condition invalidates the standard hypothesis tests; the results of the analysis are spurious therefore cannot be interpreted.

Table 4. 4: Breusch-Godfrey Test for Serial Correlation

F-statistic	17.78702			Prob. F (2,171)	0.0000
Obs*R-squared	30.13669			Prob. Chi-Square (2)	**0.0000**
	Variable	Coefnt	Std. Error	t-Statistic	Prob.
	C	-0.002	0.005	-0.354	0.724
	SPI	-0.006	0.004	-1.753	0.081
	RESID (-1)	0.449	0.079	5.636	0.000
	RESID (-2)	-0.037	0.076	-0.486	0.627
R-squared	0.172			Mean dependent var	5.57E-17
Adjusted R^2	0.158			S.D. dependent var	0.068
Prob (F-statistic)	0.000				

The problem was overcome by taking the first NDVI (-1) and second NDVI (-2) lags of NDVI variable. By so doing, the model could correlate the vegetation condition from the current month with that of the previous two months. The second lag had the highest Akaike Information Criterion (AIC) and therefore optimal. The results of the regression for this model are shown in Table 4.5 with an improved R^2 of 59.68%.

Table 4. 5: Regression of Lagged Normalized Difference Vegetation Index and Standardized Precipitation Index, Oltiasika

	Variable	Coefficient	Std. Error	t-Statistic	Prob.
	C	0.244	0.021	11.528	0.000
	SPI	0.030	0.004	6.799	0.000
	NDVI (-1)	0.515	0.081	6.324	0.0000
	NDVI (-2)	-0.218	0.068	-3.205	0.002
R-squared	**0.596827**			Mean dependent var	0.336
Adjusted R^2	0.589			S.D. dependent var	0.096
Prob(F-statistic)	0.000				

The result of the corresponding test for serial correlations is presented in Table 4.6.

Table 4. 6: Breusch-Godfrey Test for Seral Correlation for Lagged Model

F-statistic	2.181396			Prob. F (2,167)	0.1161
Obs*R-squared	4.404475			Prob. Chi-Square (2)	**0.1106**
	Variable	Coef.	Std. Error	t-Statistic	Prob.
	C	0.019	0.032	0.591	0.554
	SPI	0.002	0.004	0.471	0.637
	NDVI (-1)	-0.188	0.137	-1.373	0.171
	NDVI (-2)	0.133	0.093	1.432	0.154
	RESID (-1)	0.261	0.137	1.902	0.058
	RESID (-2)	-0.046	0.105	-0.436	0.663
R-squared	0.025			Mean dependent var	-7.50E-18
Adjusted R^2	-0.003			S.D. dependent var	0.061
Prob (F-statistic)	0.501				

The lagged model was highly significant with P-value =0.000 implying that the long-time relation between NDVI and SPI were not by chance. The resultant R^2 improved to 0.596 suggesting that 59.6% of the vegetation conditions can be explained by drought for that month as well as vegetation conditions of the previous two months alone. Other factors that account for the remaining vegetation conditions but not included in the model are (i) nonlinear NDVI response during excessive precipitation; (ii) other climatic and environmental factors, like groundwater soil moisture, solar irradiance, air temperature, solar irradiance; (iii) errors induced from the sensor and data processing including satellite navigation errors, sensor degradation, data resampling, view and zenith angle change, atmospheric attenuation, and cloud contamination; and (iv) land changes, vegetation type and vegetation species.

These results demonstrated that NDVI greenness profile for the study varies greatly according to the seasons and within the landscape, with areas towards the Chyulu Hills experiencing the least impacts. These results are similar to those found by BurnSilver and Mwangi, (2007) who found that the NDVI values varied across a calendar year and reflect the bimodal distribution of rainfall. Similarly, the results on the relationship mirrors those of Karniel *et al*. (2009) who found a significant relationship between drought and vegetation response with an R^2 of 0.69, 0.51, and 0.61, while Ji & Peters (2003) found an average R^2 of 0.58. The impacts of drought on vegetation persist for a period of up to two months, implying that it takes two months for pasture to regenerate following a drought event. The lag period is longer than the 45 days obtained by Udelhoven *et al*. (2009) who established a longer lag order of three months. Mutsotso, Sichangi, & Makokha (2018) using Climate Hazards Group Infrared Precipitation (CHIRPS found a three months' lag period between SPEI and NDVI in Kenya.

Information from the FGD conducted in the study area revealed that the drought of 1977, locally referred to as *Kangera,* was the first that resulted in livestock deaths. This was followed by the drought of 1984 referred to as the *Mwaka wa mahindi,* in reference to the yellow maize distributed as relief food supply. The community incurred huge livestock losses and responded by moving their animals to the nearby Tsavo National Park. Another drought occurred in 1997 but this was less devastating compared to the previous one. The drought of 2009 remains the worst in recent memory. It ravaged the entire Amboseli ecosystem and pastoralists were forced to move their animals as farther afield as the coastal region, hundreds of kilometres away, where most of them died because of diseases. According to IPCC (2014), climate change is expected to aggravate drought severity in Kenya's ASALs by 2050, with serious threats to pastoral livelihoods.

4.3 Effects of Biophysical Changes on Pastoralism in Oltiasika

This section presents results of objective two of the study that aimed to assess the effect of biophysical changes on pastoralism in Oltiasika area. The section presents results of the change in biophysical conditions due to land use changes due to farming, sedentarization and urbanization. It then discusses the effects of these changes on pastoral livelihood. The data used presented here is derived from Google Earth and household survey.

4.3.1 Spatial Temporal Land Use Change in Oltiasika Area

Images for the farming site were extracted from Google Earth for the period 2011, 2012, 2014 and 2016. The area under cultivation was digitized in ArcGIS to establish changes in farming activities in a sampled site of 4.38 km^2. The area experienced dramatic increase in the number of cultivated parcels between 2011 and 2016. While only three parcels (7.56 ha) were cultivated in 2011, the number of parcels cultivated in 2012 were 16 (32.28 ha). In 2014 the number increased to 26 covering a total area of 50.08 ha, but declined to 13 in 2016 with an area of 12.34 ha (Plate 4.3-4.10).

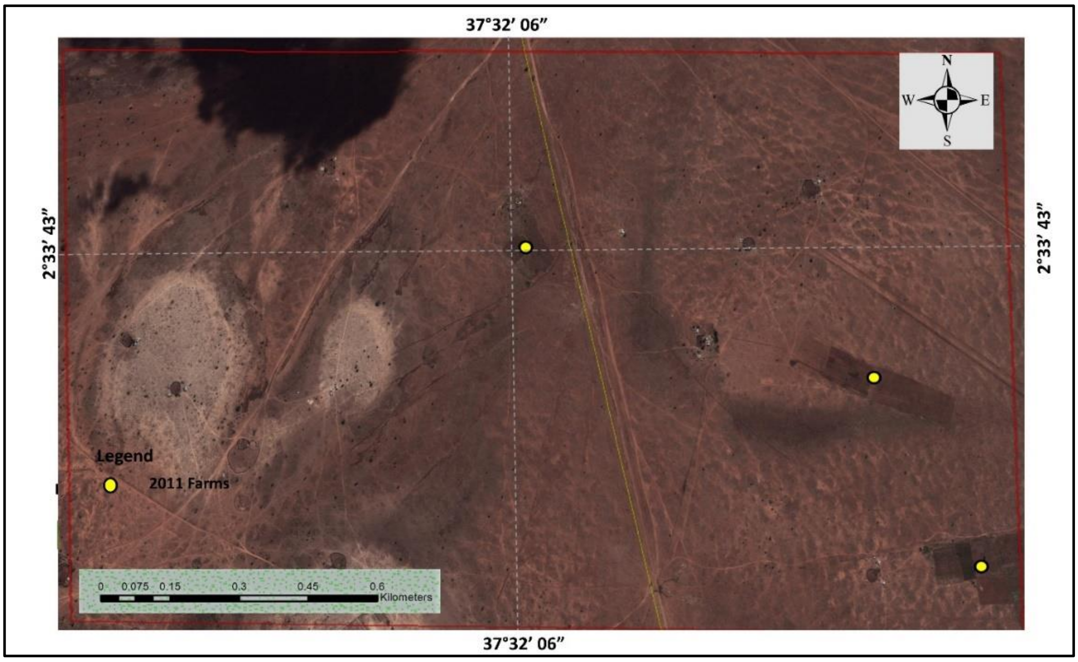

Plate 4. 3: Cultivated Farms in Sampled Site in Oltiasika, 2011

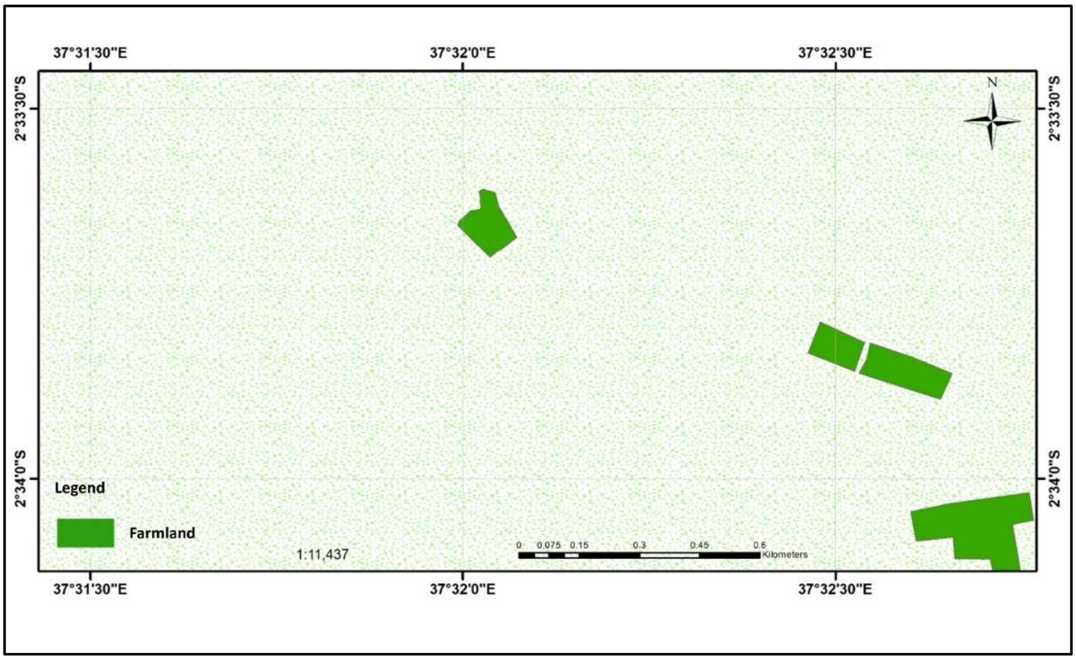

Plate 4. 4: Digitized farms in Sampled site in Oltiasika, 2011

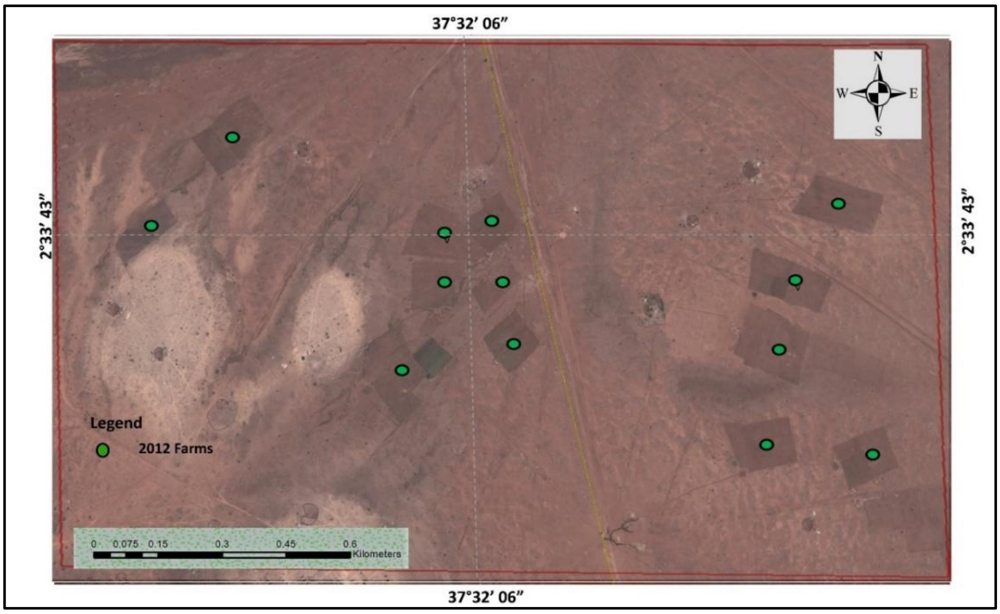

Plate 4. 5: Cultivated Farms in Sampled site in Oltiasika, 2012

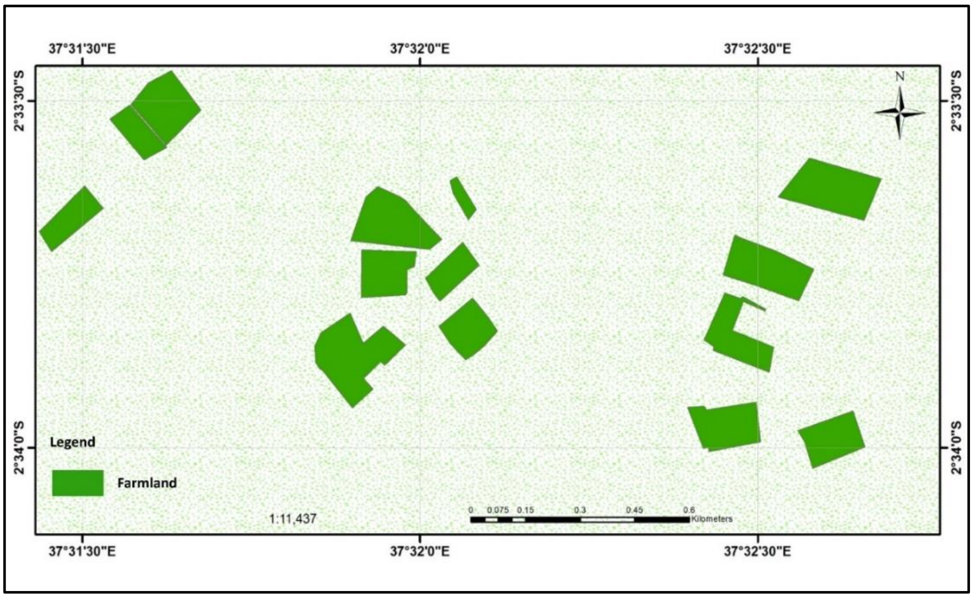

Plate 4. 6: Digitized farms in Sampled sites in Oltiasika, 2012

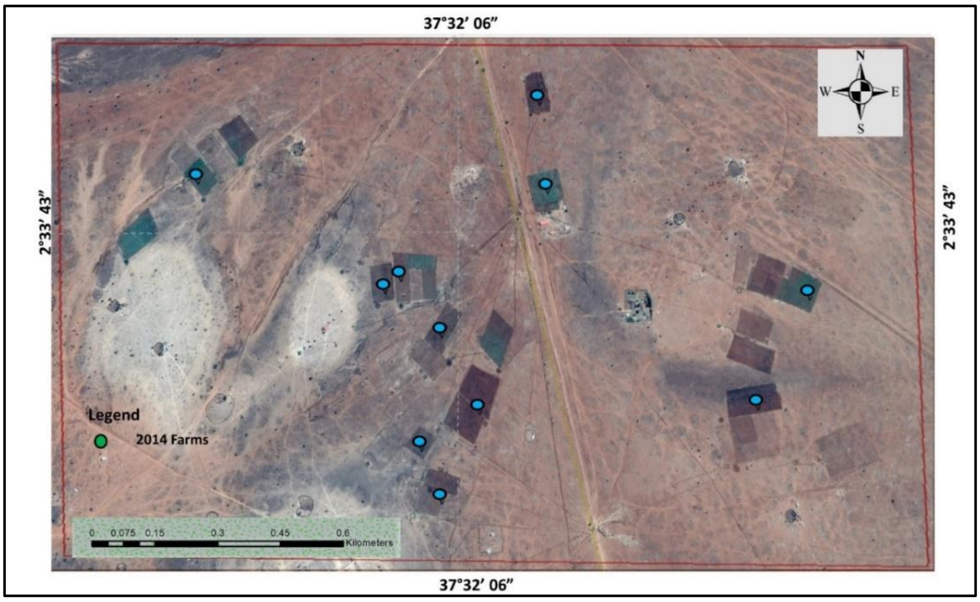

Plate 4. 7: Cultivated farms in Sampled sites in Oltiasika, 2014

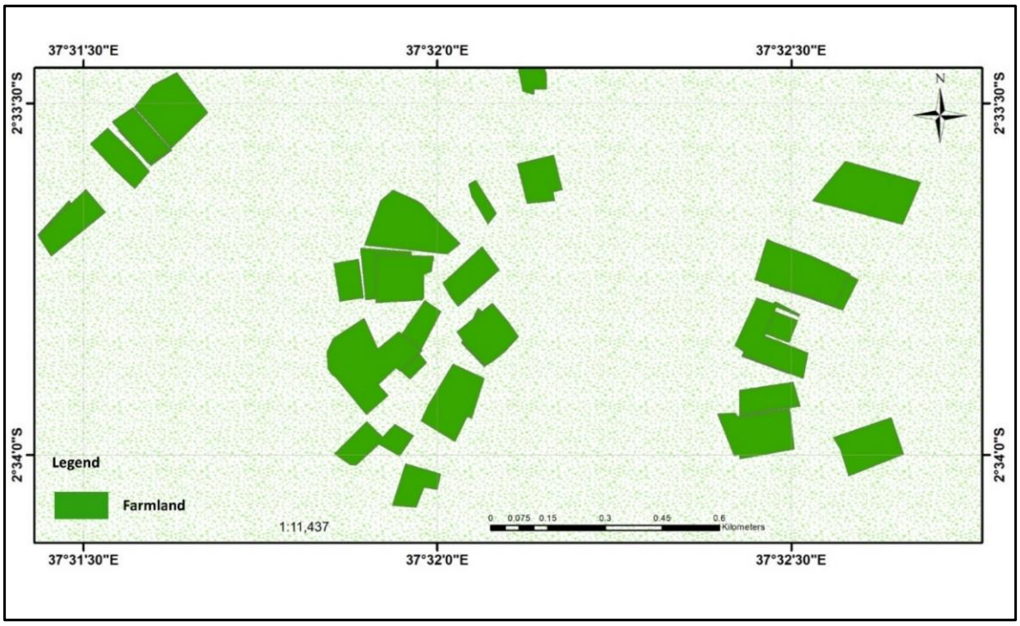

Plate 4. 8: Digitized farms in Sampled site in Oltiasika area, 2014

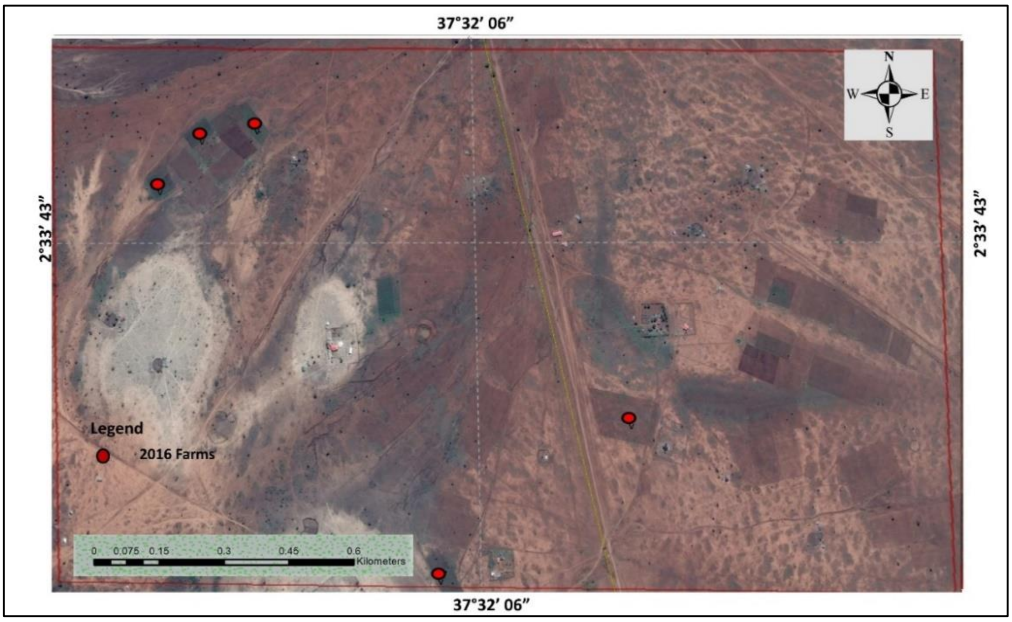

Plate 4. 9: Cultivated farms in Sampled farms in Oltiasika area, 2016

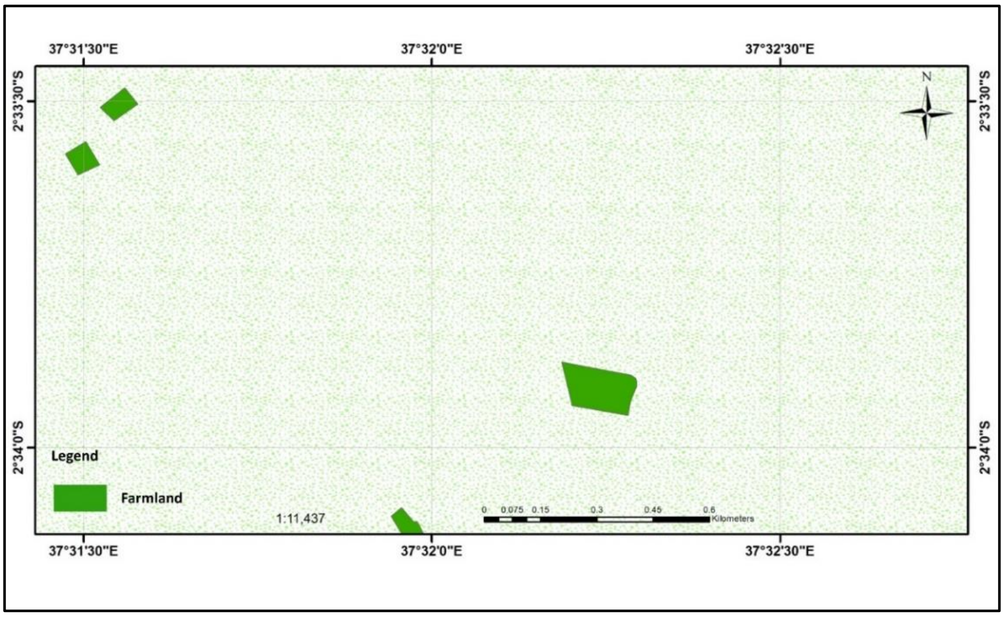

Plate 4. 10: Digitized farms in Sampled sites in Oltiasika, 2016

Thus, over the five-year period, the number of cultivated parcels increased from three to 13 parcels. Total of 13.74 ha was abandoned within the period, implying a high degree of shifting cultivation. Farms tend to be concentrated in specific points with areas to the extreme south west and northern part having relatively limited cultivation. One of the reasons is the poor soils as evidenced by the white spots towards the southeastern part.

During ground truthing of the google earth images, it was established that tomatoes were the most common crop grown followed by vegetables, maize, beans and onions. It was further revealed that cultivation in Oltiasika was introduce in early 1970s in Isinet by Kikuyu women married by Maasai men. Many of them brought other members of their families along with them and in the process agricultural settlement begun. Later Akamba and Kisii communities and even people from Tanzania moved into the area to continue with farming by renting land from the Maasai. The average cost of renting an acre was KShs. 35,000 per year. At times producers entered into an arrangement with the land owners to share the produce on an agreed ratio. Cultivation in the area picked in the period after 2000 following the tarmacking of Emali-Loitoktok road which improved market access of the produce to the cities of Mombasa and Nairobi.

Farming was not without challenges. Land upon which it was practiced lacked clear rights, as it was communally owned by members of the Mbirikani Group ranch. This means farms would be opened haphazardly resulting into indiscriminate clearing of the vegetation, thereby reducing livestock forage. Lack of water was cited number one problem facing farming as summarized by one government technical officer below:

> "…all the cultivation is either practised within the riverbeds or along the water pipeline. There is no culture of paying for water resources here, so most people irrigate their crops using illegal connections from the springs. Without any regulating, downstream users will soon not have any water for their livestock and this will create conflicts. The same thing will happen with the pipeline since it was not designed to supply water for irrigation. In my view, without solving the water questions, no cultivation should be allowed to continue' (Makutano Focus Group Discussion, February 2015).

Information obtained from the FGDs revealed that communities practised crop farming out of necessity of spreading the drought risks and enhancing survival.

Besides crop cultivation, assessment changes in human settlements in the study area was undertaken between 2011 and 2016 of a sampled site of 3.96 km^2. The results showed that the area experienced rapid population increase as evidenced by an increase in the number of Manyatta homesteads (Figure 4.12). Within the image site, the total number rose from 16 in 2011 to 25 in 2016 representing a 37.5 % change. Out of the 16 homesteads in 2011, only 10 still existed in 2016 pointing to the temporary nature of Manyatta settlement. One homestead observed in 2012 and six in 2014 did no longer exist in 2016, while eight new homesteads were established in that year.

A close observation of the patterns of Manyatta settlements (Plate 4.11) show that cultivated area increased around the homesteads. This is because having farms close to homesteads ensures security of the crops while at the same time makes it easy to provide household labour. In situations where the farms were leased out, their closeness to the homesteads was a guarantee that the produce could not be harvested without the knowledge of the landlord. This was important since the lease was based on an agreement whereby the produce was shared between the two parties. Increasing settlement constrain the movement of livestock within the rangeland and reduce the capacity of pastoralists to cope with drought.

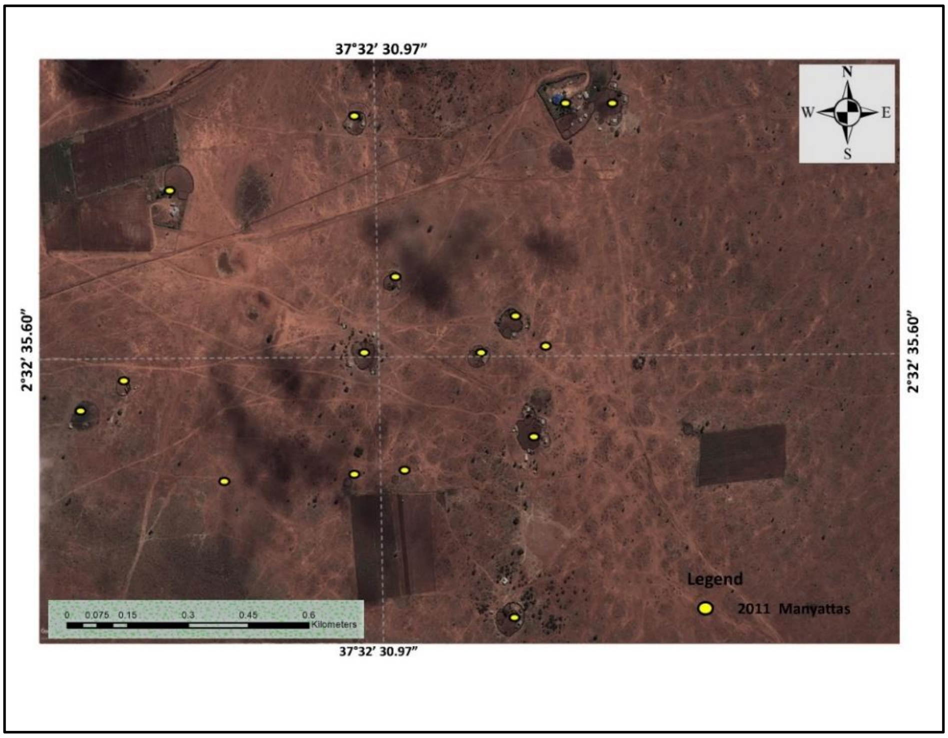

Plate 4. 11: Distribution of Manyattas in Sampled site in Oltiasika, 2011

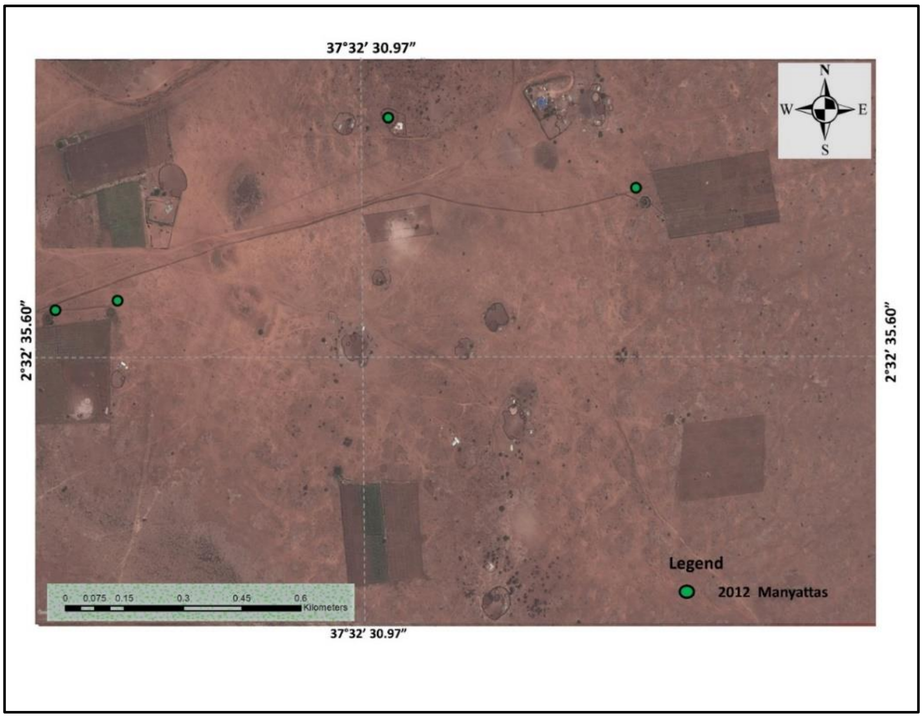

Plate 4. 12: Distribution of Manyatta is Sampled site in Oltiasika, 2012

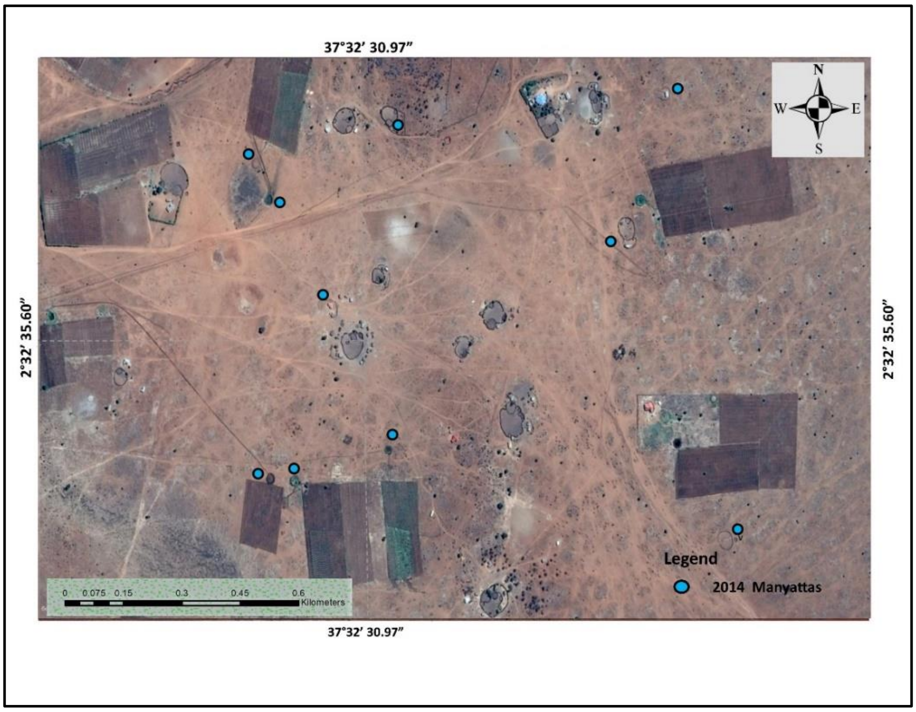

Plate 4. 13: Distribution of Manyattas in Sampled site in Oltiasika, 2014

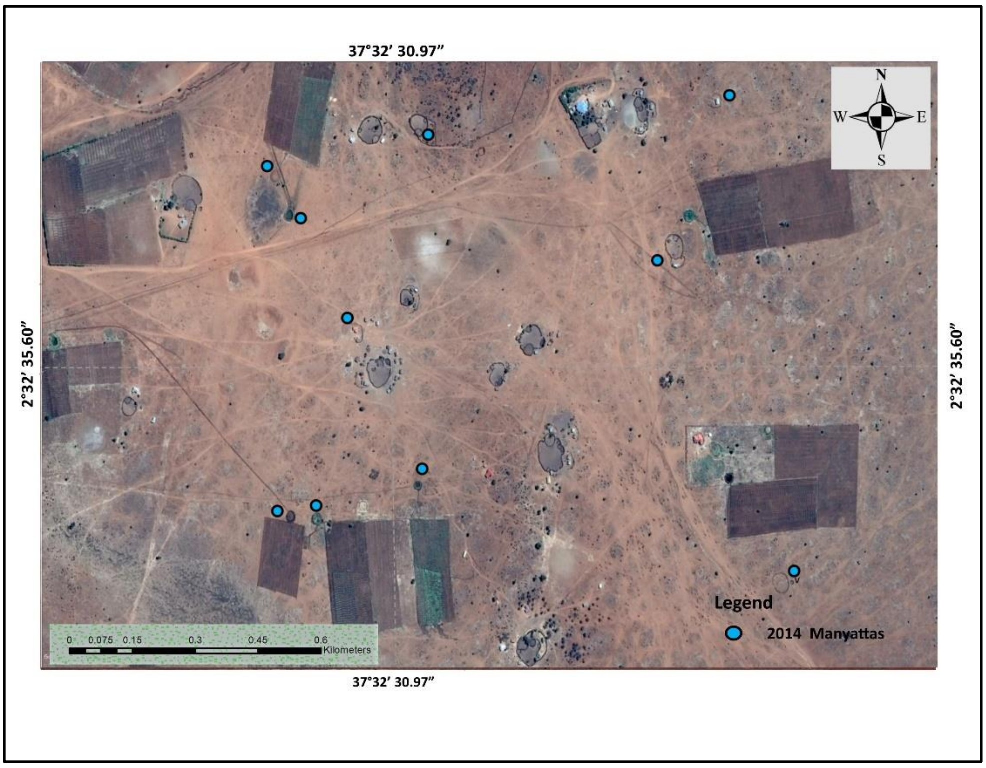

Plate 4. 14: Distribution of Manyattas in Sampled site in Oltiasika, 2016

Further assessment of the sedenteralization process was assessed through changes in permanent houses. All iron roofed houses in the area excluding those in market centres were digitized for the period 2014 and 2017. The process involved extracting vectors from Google Earth and plotting them in a vector map The number of iron sheet roofed houses increased from eight in 2014 to 25 in 2017, representing 413 percentage change (Plate 4.15 and 4.16).

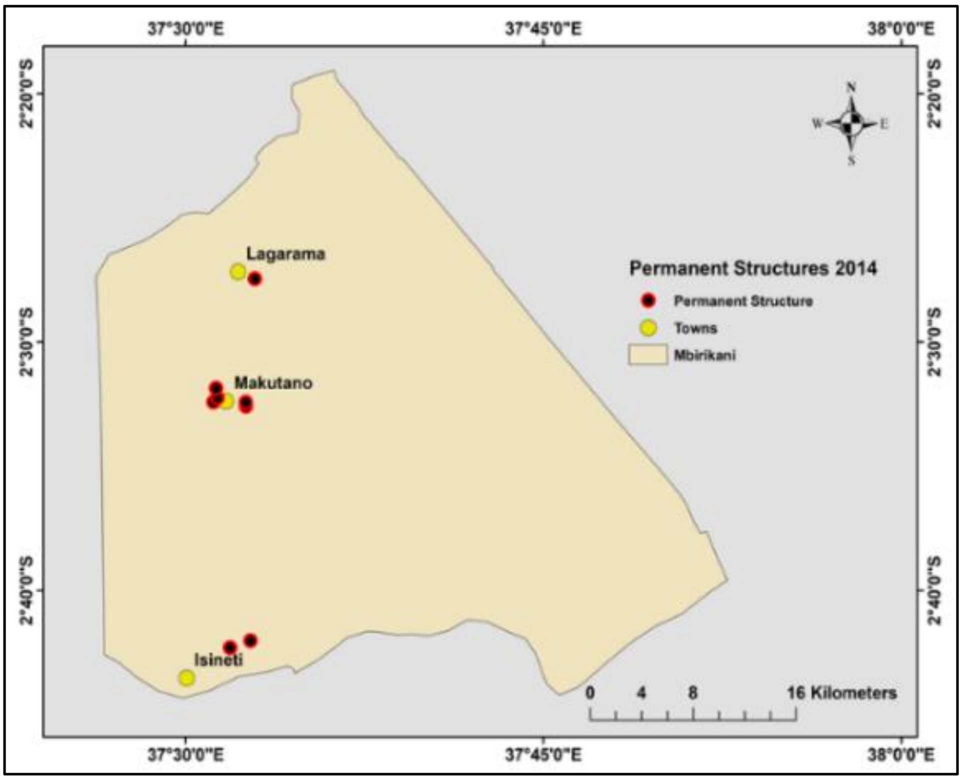

Plate 4. 15: Digitized Iron sheet Roofed Homesteads in Oltiasika, 2011

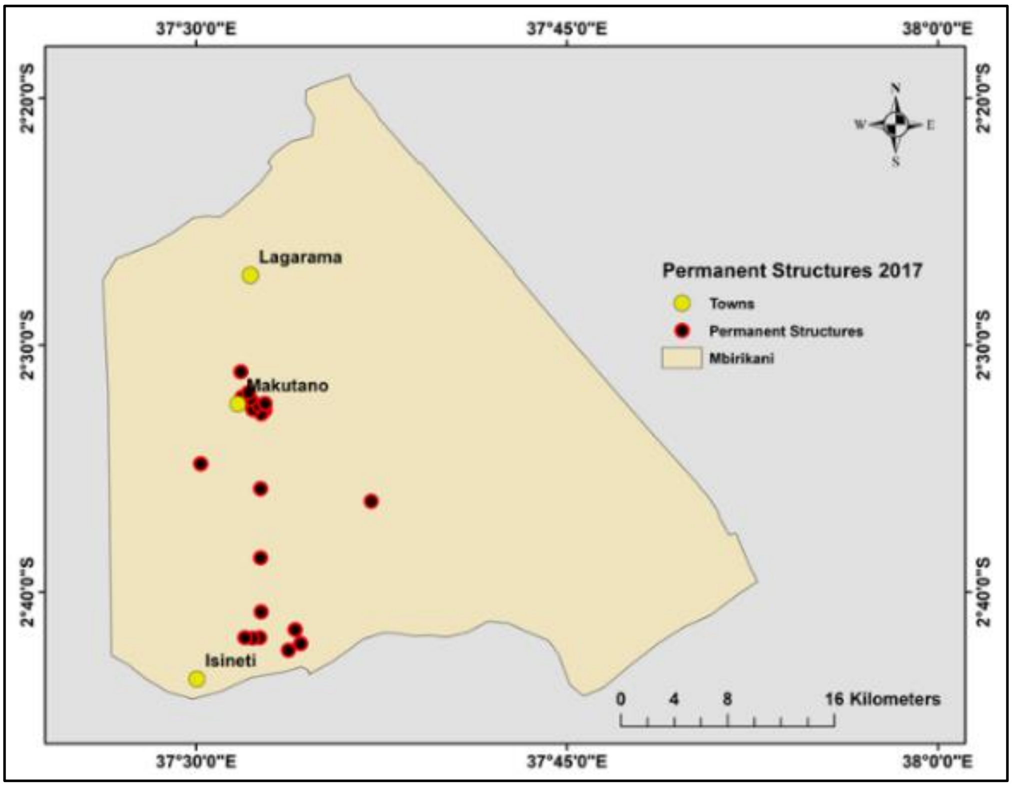

Plate 4. 16: Digitized Iron sheet Roofed Homesteads in Oltiasika, 2017

Changes in population was assessed through expansion of urbanization area. Satellite images for Makutano Centre for 2011, 2012, 2014 and 2016 were extracted from Google Earth to assess changes in buildings (Plate Figure 4.14). Between 2011 and 2016, there were 10 additional buildings, five of which were constructed in 2016 alone. This points to some degree of urbanization in an area hitherto predominantly pastureland. Other centres within the study area are Isinet and Lagarama.

Plate 4. 17: Extent of Makutano Centre in Oltiasika, 2011

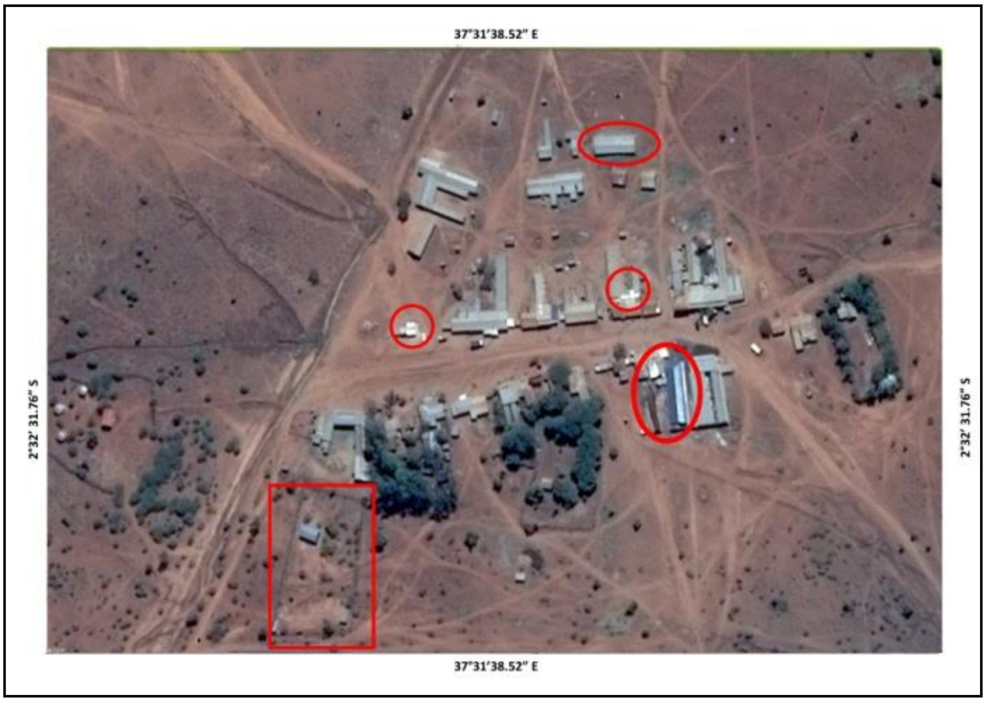

Plate 4. 18: Extent of Makutano Centre in Oltiasika, 2016

Rising population and sedentary life increased demand for social facilities as shown by the expansion of school facilities in the area. The images show that three structures were constructed between 2009 and 2014 while, four were constructed in 2016 (Figure

4.15). The area around the school has experienced intensive activities as evidenced by the intensity of footpaths. This would be due to the high number of students accessing the school attributed to high sedentary in the area. In addition, pastoralism has become less attractive to many Maasai's as the pasture resource becomes scarce. Thus, children who would otherwise be engaged in herding are now going to school. Expansion of cultivation activities reduces pastureland and create conflicts between farmers and livestock keepers.

Plate 4. 19: Satellite Image showing Chelai Primary School, 2009

Plate 4. 20: Satellite Image showing Chelai Primary School in Oltiasika, 2016

Land use changes disrupting the ecosystem structure and functions that require spatial connectivity, including wildlife migrations and extensive pastoral livestock production, thus compromising the long-term sustainability of the regional pastoral economies (Reid et al., 2008) and wildlife conservation endeavours. This analysis has demonstrated that in the past decade, the area has experienced land use changes with pastoral land being converted to farmland and human settlement, a situation that limit livestock mobility which is an important drought coping strategy.

The rising number of settlements in the study confirms the trends established earlier (Western & Nightingale, 2004), indicating that the Maasai are moving less and settling in permanent villages. For those who continue to depend on livestock the appropriation of the wetter areas and water sources by farming communities coupled with the loss drought refuges to national parks (Amboseli and Chyulus) put addition pressure on subsistence herders, increasing their vulnerability to ecological change and drought. The resource dynamics have consequently affected the livestock base as a key pastoral economy, which traditionally provided multiple functions. The fundamental functions of pastoral herds include regular provision of food in form of meat, milk, and blood, as well as cash income. Livestock is also a measure of exchange in terms of dowry, compensation of injured persons during raid, symbol of wealth and prosperity and security against drought, disease outbreak, and other rangeland calamities (Kaimba et al. 2011; Opiyo et al. 2011; Schilling et al. 2012)

4.3.2 Effect of Land Use Changes on Pastoralism in Oltiasika

From the assessment presented in section 4.3.1, the study area has undergone major land use changes between 2011 and 2016. These changes have constrained the ability of this fragile ecosystem to support pastoralism although it may be argued that they emanate from the declining ability of the ecosystem to sustain pastoralism. During drought, pastoralists usually move their livestock within the group ranch at different times to make up for fluctuations in production.

Mobility has been practiced for millennia and is the most important adaptation strategy for managing drought risks. Other strategies included longer-term mobility using temporary camps, purchase of food crops, changes in species composition, managing stocking levels, and participation in livestock market (Boone *et al*., 2011; Osano *et al*., 2013). This was enabled by the fact that the drought cycle was regular and it was much easier to predict drought and respond accordingly. Moreover, increasing drought frequency and declining cycle, means that pastoralists have little time to recovery from the drought impacts. Conversion of pastureland to farms and homesteads have limited access to pasture and water resources, therefore, exerting additional pressure on pastoralism. Other scholars argue that pastoralism is uniquely adapted to dry lands than cultivation, and that traditional pastoralism is not sustainable. Despite the arguments for sedentarization, evidence has shown that the livelihoods of settled groups were not improved as one expects (Eneyew, 2012), suggesting that settling was a necessary condition for development of pastoral lands, but it is not a sufficient condition for ensuring their development.

As the pastoral communities become more and more sedentary, the land originally available for pasture is subdivided and it's potential to support livestock declines. Despite growing concerns over group ranch subdivisions, the practice has been going on in the entire Kajiado County due to many factors, among them fear of losing land to outsiders, population pressure, poverty, alienation of land for farming and conservation, and the influence of market economies (Western *et al.,* 2009).

Land use change changes taking place in Oltiasika are not unique region. A study in Karamoja region, Uganda in 2000 found that out of an area of 2,800,000 ha only 90,650.70 (3.24%) was cropland but this expanded to 361,808.40 (12.92%) by 2011/12, representing a 300% change. Adoption of crop farming was found to be a response to declining number of livestock due to diseases and sales. Analysis of satellite data shows extensive croplands expansion between 2000 and 2011/2012. Expansion as mainly encouraged by government sponsored agricultural program that provided inputs such as seeds that were distributed at the beginning of the growing season. However, the low capacity of pastoralists and lack of constant supply of inputs led to low efficient use of land and majority of it was abandoned while percent land utilization was found to be very low (Nakalembe et al., 2017).

During the survey, the respondents were asked if they had perceived changes in climate patterns including rainfall, temperature and drought. The results show that the majority (97.16%) of respondents had observed changes in climate conditions in their locality. The rains had become less and the seasons had changed with changes both in its onset and in cessation. According to the respondents, temperatures had also increased with the days becoming hotter and nights cooler. They also reported of droughts having become more common and whenever they occurred, they persisted over a long time, as animals stay longer outside the homestead. An overwhelming (95.9%) of respondents reported that 2009 was the worst drought year in recent years compared. This view was triangulated with information obtained from one of the Focus Group Discussion as summarized by the following statement.

> "…..we don't wish to remember the great drought of 2009. The drought killed the livelihoods of many people and we have never recovered. Before the drought, a person owning 1000 cattle was considered poor. However, today you cannot find anyone with such a big herd because there is no pasture. Where we used to graze has been invaded by new types of plant species, which is not consumed by livestock. The drought brought a lot of misery among our people and we have never recovered" (Makutano Focus Group Discussion, February 2015).

Most of the respondents stated that they kept cattle, goats, sheep, and chicken with a small number reporting that they kept donkeys and dogs. Cattle was a sign of wealth, and prestige and was mainly the property of the household head, usually a man. Cattle was used for paying dowry and as source of income, and would only be slaughtered during social events such as weddings, celebrations and burial ceremonies. Goats and sheep were mainly consumed within the household thus providing food security. Besides, they were sold to raise cash to meet emergency needs such as medical bills or school fees. Fat obtained from sheep was used in preparing concoctions used for treating mothers having medical complications after delivery. Donkeys and dogs were kept for carrying luggage and security respectively.

The 2009 drought led to high livestock mortality causing a severe drop in livestock population. Prior to the drought, the number of households without any cattle before the drought stood at 27.27 % but almost doubled to 53 % at the end of the drought. Similarly, the average number of cattle reduced owned per household dropped by 67.69 % from 87.14 to 32.31. Before the drought, the maximum number of cattle owned was 1,200 but declined to 700 at the end of the drought.

Statistics on the small stock (goats and sheep) show contrasting situation. The population without any small stock (sheep and goats) increased from 22.27 % before the drought to 27.84 % afterwards, although the average number owned reduced from 101.57 to 66.76, representing a 33.24 percentage drop. The highest number for the two periods almost doubled from 1,000 to 1,820. These results show that drought effect on cattle was about twice as severe as on small stock. This is the reason their average number remained higher in 2015 compared to that of cattle.

According to the respondents, the mortality was caused by starvation and exhaustion as livestock was being moved from one location to another in search of pasture. Many cattle died while in the coastal region due to disease outbreaks, mainly coast fever, food and mouth (lukulup in Maasai), lumpy skins disease (loriri) and contagious caprine pleuropneumonia (Likipei). Death in small stock was mainly attributed by small shot pox and anthrax.

Reduced pasture affected the quality of the animals, which ended up fetching low prices in the market. This erodes household's purchasing power considering that livestock is the most important source of income. In response, pastoralist communities deploy a number of strategies mainly linked to changes in the consumption behaviours including reducing the number of meals taken per day and soliciting for food donations and gifts; and borrowing from relatives, social networks and as a matter of last resort, food relief through humanitarian assistance. Such strategies are effective in addressing moderate drought and enable household to recover quickly. As the drought becomes more severe and prolonged, the ability of households to respond is limited. These limitations relate to increased frequency of drought as well as to rising population, declining resource base, and changes in access to land and water due to sedentarization. Consequently, many households lose their livestock, which forms the basis of their livelihoods, leaving them more vulnerable to the next drought and forcing them to explore alternative livelihoods.

In response to drought and biophysical changes taking place in the area, the study found that communities had started diversifying their livelihood from livestock to other on-farm activities. It also means that frequent droughts experienced in the area made pastoralism unviable, forcing people to explore other livelihood options. Households were engaged in four main types of occupation namely livestock, crop farming, business and formal employment (Plate 4.21 & 4.22). Remittances, tourism and bead making were other livelihood activities identified in the area but only by a small number of respondents. Incomes earned from these activities were also negligible compared to the three main activities.

Plate 4. 21: Cattle in Oltiasika area, 2015

Plate 4. 22: Tomato farming in Oltiasika Area, 2015

Majority (67.61%) of respondents reported that they were livestock keepers, while a small percentage (5.11%) reported to be engaged in formal employment. These results do not account for mixed occupation. However, since the area receives very low rainfall, rain-fed agriculture is unlikely to be a viable alternative. Respondents were asked to provide incomes from each of the three sources in the last 12 months to help compute individual livelihood diversification index. For the entire sample, the average proportions income from livestock was (76%) followed by crop farming (20%) and non-farm activities (4%); indicating some shift from the pastoralism.

Further analysis of livelihood diversification was examined using the livelihood diversification index (HHD). The study found that the respondents were engaged in three core income activities namely; livestock, crop farming, business and other non-farm activities. Livestock income was obtained from cattle, goat, and sheep (small stock); while the main income sources for crops were tomatoes, maize, vegetables and other crops. Other non-farm livelihood activities comprised of wage employment, remittance, and eco-tourism.

Within the livestock activity, income from cattle accounted for an average of 28.93% compared with 71.06 for small stock. This rather surprising result tends to suggest farmers' preference towards small stock, which are more drought tolerant. Livestock income included milk off-take for own consumption, livestock slaughtered for own consumption, income from sale of livestock and sale of hides and skins. In many households, sale of milk is restricted to allow sufficient milk for the calves. Net earnings from livestock were computed by removing the costs of veterinary services, minerals supply and herding.

In situations where the respondent was not directly involved in crop farming, earnings from the shared crop production was used as the farm income. Earnings from lease of land for purposes of crop farming was considered as farm income.

To establish whether respondents still regarded livestock as an important livelihood activity they were asked whether they used any of the earnings from crops for livestock purposes in the previous season. The results indicated that 24.56% had invested earnings from other sources into livestock mainly to purchase livestock, pay for veterinary services and pay the headers. Some crop earnings were also used to purchase fodder. The level of reinvesting in livestock would be due to the farmers' perceived declining returns and may explain the low recovery of livestock numbers in the area.

Generally, participants were aware of the impacts on drought on traditional livelihood system. One FGD respondent said:

> "Severe droughts experienced in the area have caused heavy losses and made pastoralism unviable. For example, "many households lost all their livestock during the 2009 drought and have never managed to restock. They lack means to restock as they had only a single source of income. Because we don't know how to cultivate, we are forced to rely on people from outside for food. Another problem is that not everyone has access to water to support irrigation' (Key Informant Interview Mbirikani Group Ranch, February, 2015).

Earning from business was the biggest portion of non-farm activities accounting for 78 %, that from salaried income 12.45 %, while remittance and eco-tourism activities contributed to 6.53 % and 3.02 % respectively. Surprisingly, many households did not receive meaningful income from eco-tourism even though Oltiasika lies between two ecosystems renown for tourism. This is probably because although the areas are known for ecotourism, the revenue does not trickle down to support community programmes. On this basis, income sources in the study area was divided into livestock/pastoral income, non-pastoral farm (NPF) income, and non-farm non-pastoral (NFNP) income. Data on these sources for each household was used to compute household HHD using equation (3.11). Net earnings were obtained by removing the costs of inputs such as herding and veterinary in the case of livestock and seeds, labour and fertilizers in the case of crop farming.

The results for the degree of diversification showed that most respondents (51.14%) had not diversified their livelihood at all, and relied entirely on a single income source. A small proportion (22.73%) had a diversification index of less than 0.25 and this reduced further to 2.84% for respondents, whose diversification index was more than 0.5. The mean diversification index for the sample was 0.125 with a standard deviation of 0.182 and a maximum value of 0.64. These results show that single livelihood type is dominant in the study area with meaningful diversification (HHD) greater than 0.5 happening among a small number of respondents.

The study found that livelihood in Oltiasika has undergone major changes since the establishment of Mbirikani Group Ranch in 1970. This brief statement by a participant in an FGD stresses the importance of pastoral livelihood system four decades ago:

> "We used to depend on livestock for all our needs. There was plenty of rainfall and pasture and both our livestock and wildlife would move freely in the ranch. During drought, we used to graze inside Chyulu Hills'. The rains have become scarce and drought has killed our cattle so we no longer rely on livestock. To some people, farming has become an important activity as income from livestock has declined" (Makutano Focus Group Discussion, February 2015).

After 1999, drought in Oltiasika became more frequent with the shrinking of the drought cycle and at the same time became more intense. The changes are observed in declining vegetation conditions and ultimately on pastoral livelihood. Drought impacts on vegetation reduced pasture availability and overall productivity of the livestock. Given the importance of livestock in the pastoral livelihood, any reduction in their numbers affects animal-based food for households. Under such circumstances, pastoralists are forced to sell livestock in exchange for food. This exacerbates their vulnerability through erosion of capital asset, weakens their ability for post recovery, and trigger a continuous process of a positive feedback loop (Boone et al., 2005).

In Oltiasika area, drought had two main effects. First, it resulted in stressed vegetation and reduction in pasture availability, and second, it created suitable conditions for invasive plant species to thrive. Invasive species replaced perennial grass thereby affecting the quality of the pasture and generally contributed to reduction in the carrying capacity of Mbirikani Group Ranch (Ntiati 2002, Schwartz, 2005). The drought of 2008-2009 diminished the quantity and quality of pasture in Kenya's rangelands and caused huge livestock losses due to starvation. In the current study, households lost 95% of the livestock due to starvation and diseases. Government reports estimate loss due to the 2008-2009 droughts in Kajiado County at more than 70% meaning that drought impacts are localized and more severe in Oltiasika compared with the rest of the County (Huho *et al.*, 2009). Because of this, the area has experienced declining number of livestock owned by households, and affected community main diet comprising milk and meat.

Pastoralism is an age-old practice among the Maasai community in Kajiado County. Overtime they have gained a mastery of the SES of this ASAL. Under stable SES conditions, the ecological systems provided communities with pasture to meet the requirement of their livestock most of the year. Like in many other ASAL areas, SES is seldom stable but under constant disturbance from several forces working in cohort. In Kajiado County, changes in SES is due to land use changes, rising population, economic and socio-cultural transformation, and climate change (Ogutu *et al.*, 2014). It is further argued in the 19th Century, that Maasai dominated neighbouring agricultural communities and had greater physical and political access to pasture.

However, the situation has reversed since colonial and post-colonial periods as subsequent governments paid little attention to the needs of the pastoral community (Thornton *et al.*, 2006). Livelihood diversification in ASAL is constrained by limited options, dictated by the biophysical conditions. The SES in ASAL support narrow and specialized livelihood system adapted to the existing environmental conditions. Although the importance of pastoralism has declined in Oltiasika, it remains a major part of the Maasai social and economic systems; a primary goal of the Maasai is to maintain sufficient livestock to survive drought and livestock epidemics. The results revealed a shift from pastoralism to agro-pastoralism particularly over the past 20 years driven by the desire for more extensive household benefits and alternatives to the unpredictable and declining pastoral lifestyle (Okello, 2005).

With climate change, these livestock related adaptation strategies are increasingly under threat. The need to service is the main driver of diversification in Oltiasika. However, older people tend to stay in pastoralism. Pastoralists pursue livelihood diversification of non-pastoral incomes earning activities – farming, artisanal trade, diversification in animal species (Ouma *et al.*, 2012). Pastoralists rely on three income sources - dryland framing, non-farm non-pastorals activities, and pastoral income.

The results from section 4.2.12 suggest that pastoralists have responded to drought by restructuring their livestock towards more small stock for three key reasons. First, unlike cattle, small stocks can survive on poor quality pasture and therefore are less vulnerable to drought. Second, their reproduction rate is higher as they have a shorter gestation period of 150 days compared with 280 days for cattle, and third, during drought, it is easier to convert them to cash to purchase food (Hugo *et al.*, 2011). The Masaai traditionally depended on livestock as a source of milk and meat, and occasionally supplemented their diet with grains and legumes obtained from the market.

Crop cultivation was the most important diversification activity in the area. The negative relationship between livelihood diversification and household resilience may be explained by the low participation of the local communities in the diversification process and the existing cultivation system. First, it is argued that for livelihood diversification to address household resilience, the participation of the local communities is important. However, this is not the case as most local pastoralists seldom undertake farming directly, but merely benefit from land leases, which is very small compared to the value of the produce. Due to this, the benefits are insufficient to bridge the gaps in food deficits during famine months. Second, the bulk of what is grown in the area is not available for local consumption but exported to urban area outside Oltiasika. Therefore, although those households who leased land received money from land rent, they faced problems of food availability just like everyone else.

Considering that the group ranch is managed under a common pool regime, where members have no restrictions on the number of animals, it is subject to rivalry as farmers compete to increase their stock. However, lessons from recent drought show that the impacts of drought can be so devastating that when farmers lose livestock; it takes very long to recover. Analysis in this study show that the average number of livestock owned by households were much lower than the period before the 2009 drought, an indication that the farmers are yet to recover. A study in Ethiopia showed that the impact of the drought on farmer income and consumption persisted for more than a decade (Dercon, 2004).

Livelihood in Oltiasika area has evolved in response to variable, unpredictable and extreme environmental conditions. As argued by Hansen *et al*. (2014), drought impacts can be both *ex post* and *ex ante*. *Ex post* impacts are an outcome of climate shock while *ex ante* impacts refer to opportunity costs associated with conservative strategies that risk-averse decision makers employ in advance to protect themselves against the possibility of climate shocks. Based on the study findings, livelihood diversification tends to be motivated by the need to minimize the impact of future drought.

An important finding in this research is that pastoralists who generate revenue from crop farming are slow to restock their livestock. The wait-and-see attitude implies that most of them are not sure of the changing climate patterns and its impacts on pasture and casts doubt on the future of pastoralism in this area. A study by Wangai *et al.* (2013) in Kuku Group Ranch showed that the Maasai people were willing to restock after a drought, actual restocking was not constrained by ecological and financial factors.

Pastoralists are confronted with multiple problems which have increasingly limited their capacity to respond to drought. These include increasing occurrence of drought, rising population, changes in access to land and water, and dwindling resource base. Consequently, many are losing livestock which is an important source of livelihood. This situation makes them more vulnerable to future drought. Among Kenya's pastoralists, the reduction in the drought cycle allows little time for recovery between the shocks, thus exposing their livelihoods. Studies have also demonstrated that rural households adjust their livelihoods as a matter of necessity to provide for 'self-insurance' so that the likely impact of a drought is minimized (Pandey and Bhandari, 2009).

Diversification is meant to enhance household capacity to meet immediate needs for survival under extreme conditions such as food (Hansen *et al*., 2004). Livelihood diversification in Oltiasika area aimed to reduce the period of income shortfalls and mainly include shift in livestock structure, diversification to crop cultivation and other non-farm activities. From a sustainable livelihood perspective, households exploit the range of capitals available to prevent shortfall in consumption a result of climatic shocks. In other words, diversification is meant to ensure that the household are able to meet basic necessities such as food under extreme climatic conditions, including reliance on public relief and safety-net programmes and exploitive environmental management practices (Hansen et al., 2004; Pandey and Bhandari, 2009). Although crop farming is an important livelihood diversification strategy in Oltiasika, the low and unpredictable rainfall experienced in the area makes rain fed agriculture a low return occupation, and one no less exposed to drought than pastoralism (Devereux, 2006; McPeak *et al.*, 2011). Some scholars argue that irrigated agriculture can indeed be viable in ASALs (Awulachew, 2010), practised by those who have 'dropped out' of pastoralism (Sandford, 2013). The situation in Oltiasika is different as cultivation was first introduced in Isinet in the 1990 by farmers from Kimana, Namalok, and Rombo.

Further, crop farming is found within the riverbeds and along the Noolturesh pipeline, and does not include pastoralist 'drop-outs'. Pastoralists mainly leased land to farmers from outside Kajiado County. The viability of crop farming is greatly aided by readily available market in Nairobi and Mombasa Cities. This reinforces the assertion that irrigated agriculture is ASALs can be profitable in the presence of export opportunities (Devereux, 2006), although this requires high initial capital, labour and skills. However, diversification away from livestock among Maasai is hindered by high cultural values they attach on livestock compared to irrigated crops.

Surprisingly, other forms of diversification like collection and sale of natural products, such as charcoal, firewood, and gum resin were minimal, perhaps because group ranches occupy most of the surrounding areas, while the Chyulu forest is a protection area thus limited access and exploitations of resources. This implies that opportunities for off-farm diversification are few and on farm activities hold the future of the pastoralists in this area.

The results indicate that most pastoralist who lease out land for irrigation do not reinvest the income in livestock, and have not restocked to their levels prior to the 2009 drought. In contrast, in Baringo, pastoralists' driven out of pastoralism by loss of herds through conflict were involved in irrigation to recover and build up their herds again so that they could once again become viable pastoralists (Sandford, 2011). This prospect is threatened by frequent droughts and subdivision of the group ranch to grant individual member's private rights. Ranch subdivision would encourage a more sedentary nature of their lifestyle, and limiting the range of their livestock movements. Sedentary would seriously compromise any prospects of pastoralists to revert to full-time pastoralism.

Non-livestock related food would be obtained by exchanging with livestock of by cash purchase. Whenever household lost their livestock, they would resort to other assets to reconstruct their livelihood. In situation where they leased a portion of their arable land, the revenue was an important asset used to purchase food staff to fill the gap in the reduction or loss of livestock. If the household opted for crop production system where the produce is shared out, they would be used to address the household food requirements during drought. Whichever the case, households involved in cultivations are expected to have higher drought resilience in terms of fulfilling the household food requirements.

Among the Maasai, diversification away from traditional pastoralism is matter of necessity. Changes in environmental conditions limit ability of traditional livelihood to meet the present needs, while, some households diversify to maximize opportunities created by changes in culture and social-economic conditions. The findings demonstrated that conversion of pastureland to cropland was an important reason why the Maasai were abandoning pastoral livelihoods. Those who drop out of pastoralism were further marginalized as they lacked the knowhow and means to participate in farming.

Crop cultivation is a recent activity among pastoral communities in Eastern Africa. A study in Simanjiiro District, Tanzania found that crop farming was started in 2000 and during seasons with good rainfall, the Maasai pastoralists cultivated land to produce crops to feed their households from their own crops. However, when the rainfall is unreliable and the yields are poor forcing them to resort to selling cattle (Yanda and Williams, 2010).

Not all diversifications have the same potential to enhance pastoralists' vulnerability. Despite being favoured by polices makers, farm-based activities are often confronted with scarcity of water resources, implementation challenges, and poor access to markets. Investment in non-farm activities particularly in education tend to have large pay-offs, including promoting sustainable income diversification, influencing fertility reduction and improving the skill level of local communities to better participate in diverse livelihood activities (Headey *et al*., 2014).

4.4 Assessing Livelihood Diversification among Pastoral Community

4.4.1 Livelihood Diversification Index for Sample Index

Respondents who had diversified their livelihood were separated from the sample to form a sub-sample and their spatial distribution plotted (Figure 16). Three core income activities were identified in the area; livestock, crop farming, business and other activities. The average proportion in income from livestock was (76%) followed by crop farming (20%) and non-farm activities (4%) indicating some shift from the traditional pastoralism.

The sub-activities under livestock were cattle and goat/sheep; those under crop farming were tomatoes, maize, vegetables and other crops, while non-farm sun-activities included business, salaried income, remittance, and others. Within the livestock activity, income from cattle accounted for an average of 28.93% compared with 71.06 for goats and sheep. This rather surprising result tends to suggest farmers preference towards small stock, which would be more drought tolerant. In the crop category, tomatoes contributed the highest to crop income (69.0%) followed by vegetables (14.45%), maize (8.53%) and the remaining (8.02%) other crops. The contribution of business to non-farm activities was 78 per cent, that of salaried income 12.45% while those of remittance and eco-tourism activities were 6.53 per cent and 3.02 per cent respectively.

To compute individual diversification index, respondents were asked to provide incomes from each of these sources in the last 12 months. For the sample, income from eco-tourism was lower than expected despite Oltiasika being located between two systems known for tourism. This is probably because tourism revenue does not flow directly to individuals but rather through community programmes.

The livelihood diversification index (HHD) for the sampled population was computed from per equation (12). The results showed that majority of respondents (51.14%) had not diversified their livelihood at all. A small proportion (22.73%) had a diversification index of less than 0.25 and this reduced further to 2.84% for respondents whose diversification index was more than 0.5. The mean diversification index for the sample was 0.103 with a standard deviation of 0.176 and a maximum value of 0.692. The profile of the HHD for the sample is shown in Figure 4.8.

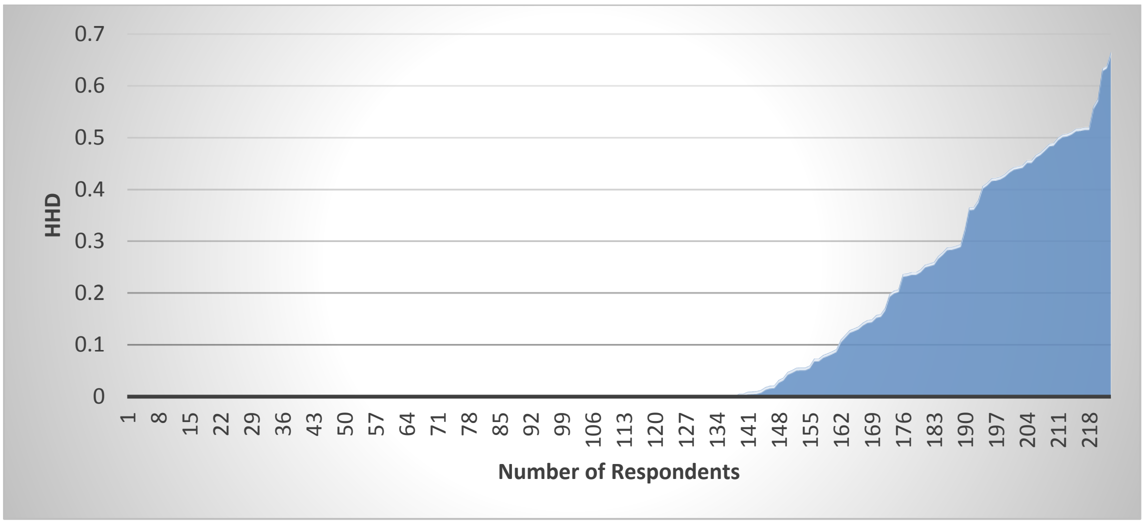

Figure 4. 8: Profile of Livelihood Diversification Index for Oltiasika Area

These results show that single livelihood type is common in the study area and less than 7% of the respondents had a diversification index of more than 0.5.

4.4.2 Effect of Livelihood Diversification on Household Food Resilience

Under objective three, the study sought to gain understanding of how livelihood diversification influence household resilience to drought. This was accomplished by running an ordered logistic model using the diversification index generated in section 4.3 and the household food security index. The results are based on the data obtained from the household survey. The first part of the section summarizes the statistics of the model variables while the second part presents the results of the model.

From the survey data, the samples had a mean age of 41.85 years with 36.36% of them below 35 years. The minimum age was 15 years while the maxim was 72 years. Compared with youthful respondents, older people were reported to be risk averse and therefore less receptive to new ideas necessary to encourage livelihood diversification.

The survey sample had an average household size of 7.6 members with minimum of one and a maximum size of 21. About one third of respondents had a household size of more than nine members. In some cases, a group of three to four households were combined to form a *boma* as it has been the tradition in most of Maasai land. However, this has reduced in recent years due to increased adoption of capitalistic tendency and the desire to claim stake to land in the event of a subdivision of the group ranch. Household size is expected to determine the labour force, which in turn, affects household capacity to engage in multiple livelihoods. Larger families have more labour that can be deployed to multiple livelihood activities.

More than half of respondents (51.14%) had no formal education while more than 32.95 % had not received formal education beyond primary school. Cumulatively, 84.09 % of respondents had only primary level education. A small proportion (3.41%) had tertiary level of education. Assuming post-primary schooling is necessary for one to attain a basic education, the results show respondents with high illiteracy levels. One's education is expected to increase the likelihood of adopting new idea such as livelihood diversification. Further, educated individuals are expected to possess higher adaptive capacity to climate extremes through better access, processing and use of information. In the study area, educated household heads tended to be appointed to positions of leadership, which exposed them to new ideas.

The bulk of land in the study was communally owned, with communities only having access to land group ranch, although people still owned other parcels of land outside the study area. Information on land owned was obtained from respondents. About 60% of respondents had a single parcel, 33% owned two parcels 4% three and only 2.3% had four. A small proportion (1.1%) did not own any land. The amount of land owned by a household determines the land under farming, which in turn, influences one's probability to engage in multiple livelihood activities.

Information obtained through key informant interviews confirmed ownership to multiple pieces of land might be due to recent delineation of urban areas from the group ranch. Isinet market centre, for example, had been surveyed and plots allocated to some members of the groups ranch. Respondents without land mainly were migrants into the area, who were engaged in activities such as causal labour, retail business, or crop farming. Only 43 respondents reported to possess a third parcel, which was generally bigger with an average of 8.25 acres compared with 1.72 and 3.73 acres for the first and second parcel respectively.

A follow up question sought to establish the size of each parcel either owned or accessed, its distance from the homestead, the current user and the purpose for which that land was put, in the past 12 months. For land where the homestead was located, the distance was fixed at zero. For respondents who had more than one parcel of land, the average distance from the homestead ranged from a minimum of 0.34 km to a maximum of 70 km. The minimum represents those parcels within the study area while the maximum are parcels located outside the group ranch majority of which were in Loitoktok. Analysis on the users of land within the group ranch indicated that 83% of respondents were exclusive users of the land. The remaining 17% reported that part of their land was leased out, and used for crop farming. Government policy towards sedentary settlement encouraged individual land ownership and crop farming.

Within the Sustainable Livelihood Framework, assets are a vital component of a livelihood system. Information on various types of assets was obtained from the respondents as well as its value in Kenya shillings. Data on the value of assets showed that the value of the total mean assets owned was KShs. 216,117.70, with minimum of KShs. 2,500 and a maximum of KShs. 1,912,000. Apart from assets, data on income from off-farm sources was obtained and analysed to provide insights on the importance of these activities on livelihood. The results show that three non-farm activities were important, namely formal employment, labour wages, and business. Wildlife-based income was another source of earning but its share in the overall income was negligible. It is expected that the higher the assets one owns and income level, the greater the capacity to engage in alternative livelihoods. Under extreme conditions, households tend to dispose a part of their assets to meet basic needs.

The findings also show that the sampled households had diversified their productive strategies. Although livestock was still the dominant economic activity, the contribution of other activities was an important component of the household income. Livestock revenue represented an average of 76% of household income, and mainly came from sale of livestock. Milk was managed by women and was mainly for household consumption. Income from crop farming for the sample was 20% while non-farm activities comprised only 4%. The average livelihood diversification index for the sample was 1.191, with a minimum value of 0.252 and a maximum 2.882.

Among sampled households, livestock remain a dominant livelihood activity, with majority of respondents (76.14%) reporting that they owned livestock compared with 23.86% who did not. Livestock is an important resource for the Maasai community, acting as both capital and saving resource for most households. Further, livestock provided food and nutritional needs of the community and the number of livestock one kept determined his status in the society. Cattle, sheep and goats (small stock) were the most important livestock kept. Among the Maasai community, sheep and goats are usually put under common grazing system and respondents often counted them together as shown in Plate 4.1. According to the respondents, the number of livestock per household was reported to have declined considerably over the past years.

Plate 4. 23: Photo showing small stock in Oltiasika area

The situation of livestock in the current period as well as in the past 10 years is presented in Figure 4.9.

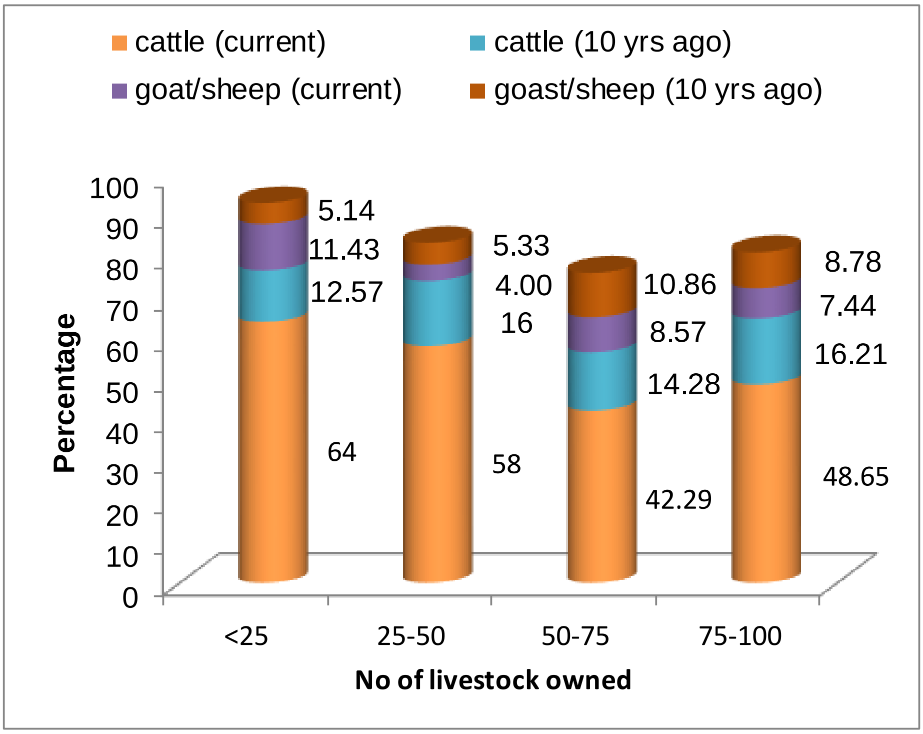

Figure 4. 9: Changes in Number of Livestock Owned in Oltiasika Area, 2005-2015

Further analysis indicated that the average number of cattle dropped from 58.00 five years ago to the current 38.69, while that of small stock increased from 91.73 to 93.32. Similarly, the maximum number of cattle declined from 3000 to 800, equivalent to 73 % drop, while that for small stock declined from 3000 to 2000 representing a 33 % drop. Comparing the current and past data was necessary to give the researcher the impression on any changes in the structure of the livestock. By selecting five-year period, the researcher hoped to capture the impact on livestock numbers of the 2009 drought.

Respondents reported that over the past 12 months, they had sold an average of 3.82 cattle and 58.73 small stock. The number of small stock were almost 20 times more than that of cattle pointing to their importance and a shift in livestock structure. The average cost of cattle was KShs. 21,587, about four times that of small stock. Although the average price of small stock is lower than that of cattle, the average number sold is about 15 times more. The mean annual income from cattle was KShs. 132,018, while that from goats was KShs. 461,281. Cattle were mainly only sold to meet major cash obligations like paying school fees while the small stock was sold to finance household consumption. Further, unlike cattle which were slaughtered during major community ceremonies, goats were important sources of household meat supply. Further interrogation of livestock earnings revealed total annual earnings from livestock was KShs. 593,330 with net earnings of KShs. 457,074. Respondents incurred some costs to keep livestock. The main ones were labour for the header and veterinary services. The mean net income for the sampled respondents was KShs. 31,522.67.

Traditional strategies for coping with drought among the Maasai included movement of livestock away from the homestead in search of pasture and water; family support in terms of livestock loans and reciprocal grazing arrangements. The creation of Amboseli and Chyulu national parks between Oltiasika ecosystems reduced the available dry season grazing zones for the community and increased the pressure on resources within the ranch. Under extreme drought conditions, many people still move their livestock to the national parks despite the prohibition, causing conflicts with the park management.

Drought is not a recent phenomenon in the area and communities have over time developed various drought coping mechanisms albeit in a limited scale. Of the sample, 55.07% reported that they had taken some measures to adapt to the negative effects of drought (CADPT), while the remaining 44.93% had not taken any form of adaptation. Four main responses were recorded, namely, reduction in number of livestock (34.09%), crop farming (27.27), fodder management (9.09%) and shift to other non-farm activities (6.81%). For those engaged in crop farming, all of them were practicing irrigation due to inadequate and unpredictable rainfall. On the source of water (IRSOURCE), 32.30% of respondents who are engaged in crop relied on swampy and spring water particularly from river Isinet. The remaining (39.01%) irrigated their crops using water from the Noolturesh water supply traversing the area to River Athi.

To assess the effect of alternative livelihood on household resilience to drought, the study analysed the number of months a household did not have adequate food for all members during the past 12 months. The results showed that an overwhelming 88.07% did not have enough food, while, the remaining reported the contrary. Food availability per month was determined and plotted (Figure 4.10). The month of February had the highest percentage (86.36%) of the respondents without adequate food, followed by January (84.66%) and December (44.32%). The months of May to September had the lowest proportion, while none of the responded was unable to provide for his household during the month of October. The results mean that community in this area experienced seasonal food insecurity.

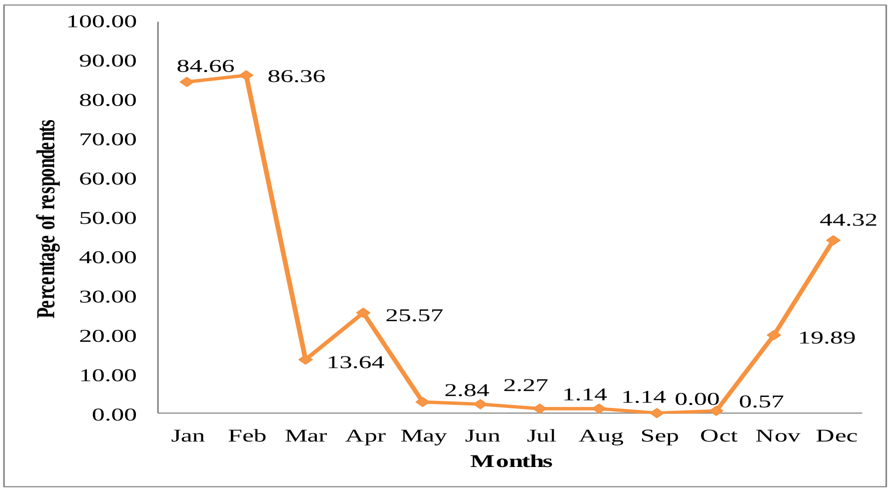

Figure 4. 10: Monthly Variation in Household Food Availability in Oltiasika, 2015

The average number of months for the sample was 3.14 with a standard deviation of 1.37, a minimum of zero and a maximum of six months. The low levels for the months of November correspond to the harvesting season of major crops grown in the area as well as in the neighbouring area when supply is high and prices low. Further, the effect of livelihood diversification on household food resilience (RESIL) was examined as outlined in Section 3.8.3. The number of months a household did not have adequate food was used as a proxy for household resilience. Thus, the higher the RESIL, the lower the household resilience and vice versa. It was hypothesized that HHD increases the coping capacity of households to drought and, therefore, reduces the number of months one did not have adequate food. A summary of the descriptive statistics for continuous variables used in the ordered model is presented in Table 4.7.

Table 4. 7: Descriptive Statistics of Continuous Independent Variables

Variable	Sample size	Mean	Std. Dev	Min	Max
Age	227	41.89	13.854	15	72
Livelihood Index	213	1.191	0.359	0.252	2.882
Total Asset	227	216117.7	293021.3	2500	1912000
Net income	225	31522.67	71403.43	0	486000
Household size	227	7.612	2.8912	1	21

Descriptive statistics for binary and categorical variables of the Ordered Logit Regression model are presented in Table 4.8.

Of the total respondents, 40.71% had low resilience index, 35.4% had moderate resilience, 15.04% very low and 8.05% strong resilience. About half (51.1%) of the respondents had no formal education, 31.72 % had primary school level of education, 11.89 secondary school level while only 5.29% had tertiary level of education. In terms of occupation, 70.48 % of respondent were engaged in livestock keeping as a primary occupation, 18.94% in crop farming, 6.61% business and the remaining 3.96% relied on salaried and wage employment.

For those respondents who were engaged in crop farming, 56.15% obtained water from swamp, 30.77 % from the pipeline and the remaining 13.00 % form dams. On crop diversification, respondents had two options on where to produce their crops; land within or outside Oltiasika. A whopping 96.48% leased land within Oltiasika compared to 79.30% who leased land located outside Oltiasika. Almost half (55.07%) of those who had perceived climate change had implemented adaptation measures while the remaining 44.9 % did not.

Table 4. 8: Tabulation of Categorical Variables of the Logit Model

	Frequency	%	Cumulative %
Household Resilience			
Strong	20	8.85	8.85
Moderate	80	35.40	44.25
Low	92	40.71	84.96
Very Low	34	15.04	100.00
Highest Education Level			
No Formal	116	51.10	51.10
Primary School	72	31.72	82.82
Secondary School	27	11.89	94.71
Tertiary	12	5.29	100.00
Primary Occupation			
Livestock	160	70.48	70.48
Crop	43	18.94	89.43
Business	15	6.61	96.04
Salary	9	3.96	100.00
Irrigation Source			
Swamp	24	56.15	56.15
Dam	6	13.08	69.23
Pipeline	13	30.77	100.00
Lease of land within Oltiasika			
Yes	2	3.52	3.52
No	41	96.48	100.00
Lease of land outside Oltiasika			
Yes	34	79.30	79.30
No	9	20.70	100.00
Climate Adaptation			
Yes	47	55.07	55.07
No	39	44.93	100.00

The empirical relationship between livelihood diversification index (HHD) and household resilience (RESIL) were examined by running the Ordered Logistic Regression model shown in equation 13. The analysis produced the results presented in Table 4.9.

Table 4. 9: Parameter Estimate for Ordered Logit Regression

Household Resilience	Coef.	P- Value
Age	0.0309*	0.006
Household Size	-0.042	0.392
Education Level	0.079	0.704
Occupation	-0.649*	0.003
Diversification Index	-0.921**	0.073
Total Assets	$-1.28e^{-06*}$	0.027
Lease of land 1	-1.583**	0.079
Lease of land 2	0.361	0.333
Climate Adaptation	0.529**	0.087
Irrigation Source	0.243**	0.050
Net Income	$4.85e^{-06**}$	0.052
Sample Size N=212		
LR Chi-Square (11) = 28.09		

*Significant at 5%; ** Significant at 10%

The model yields a Chi-square of 28.09 with 11 degrees of freedom corresponding to the number of independent variables. Since this is a general ordered model, only the signs of the coefficients are interpreted. The positive sign of the coefficients of age, education level, leasing of land, adaptation to climate change, source of irrigation water and net non-farm income show that an increase in any of these variables increase the likelihood of a household being in a higher category of household resilience and, therefore, less resilient. On the other hand, the negative sign of the coefficient of household size, one's occupation, livelihood diversification index, total assets, and lease of primary land show that if these variables increase there is a high likelihood of a household belonging to a lower household resilience category and, therefore, greater household resilience. To gain a further understanding of the independent variables' influence on household food security, marginal effects were computed and the results for strong, moderate and low resilience are presented in Table 4.10.

If age increase by one unit, there is a 0.5% less likely to for a household to belong to strong resilience category or, 0.5% less likely to have moderate resilience and 0.3% more likely to have a low resilience. If household size increases by one unit, there is 0.8% more likely for a household to fall in the category of strong resilience, 0.6% less likely to belong to moderate resilience and 0.4 % less likely to fall within low resilience category.

Table 4. 10: Marginal Effects for Ordered Logit Model

Variable	Strong Resilience		Moderate Resilience		Low Resilience	
Household Resilience	dy/dx.	P Value	dy/dx.	P Value	dy/dx.	P Value
Age	-0.005	0.008	0.005	0.011	0.003	0.008
Household Size	0.008	0.394	-0.006	0.396	-0.004	0.395
Education Level	-0.015	0.705	0.012	0.705	0.007	0.705
Occupation	0.120	0.005	-0.096	0.008	-0.064	0.005
Diversification Index	0.171	0.080	-0.135	0.087	-0.092	0.076
Total Assets	$2.37e^{-07}$	0.003	1.89e-07	0.038	-1.28e-07	0.031
Lease of land 1	0.256	0.014	-0.045	0.624	0.264	0.201
Lease of land 2	-0.067	0.335	0.049	0.290	0.039	0.372
Climate Adaptation	-0.097	0.009	0.076	0.088	0.054	0.098
Irrigation Source	0.045	0.057	0.036	0.064	0.024	0.053
Net Income	$-8.99e^{-07}$	0.058	-7.16e-07	0.007	4.86e-07	0.055

(*) dy/dx is for discrete change of dummy variable from 0 to 1

A unit increase in years in education makes a household 1.5% less likely to belong to strong resilience category, 1.2% more likely to belong to moderate resilience and 0.7% more likely to belong to low resilience. While unit changes in total assets and net non-farm income have little effect on one's resilience level, a unit change in livelihood diversification makes a household 17.1% more likely to belong to strong resilience category, 13.5% less likely to belong to moderate resilience, and 9.2% less likely to belong to low resilience category. Based on these results, the null hypothesis that household's resilience to drought is not influenced by the degree of livelihood diversification is hereby rejected.

These results amplify the claim that households with more diversified livelihoods have higher capacity to respond to drought. It has been shown that among the Maasai community, diversification away from traditional pastoralism is a matter of necessity as well as the need to maximize opportunities created by changes in culture and social-economic conditions (McCabe *et al*., 2014). A study in Kajiado County found that total cultivated area of the household in acres, education of household spouse, age of household head and non-migrant livelihood had influence on household food availability (Omondi *et al*., (2015). However, these findings should be taken with caution. Rainfall is highly unreliable and unpredictable to sustain rain-fed agriculture. As a result, crop farming is mainly concentrated in swamps and along the Noolturesh pipeline to take advantage of available water.

Expansion of cultivation and other land use changes is likely to undermine the natural resource base, and affect the ability of this fragile ecosystem to sustain the age-old pastoral livelihood. The land use changes taking place in the area are influenced by the transformation that have been witnessed in Kajiado County for a long time. These changes can drive by process of the interaction between biophysical and social processes at the local level and national political economy context. The interactions are a result of policies on land and agriculture that have been implemented by the government before in three epochs. The first epoch, the early colonial (1900-1930) was governed by a land policy which was mainly characterized by land expropriation, large-scale agricultural production, European settlements, and restriction on Africans from participating in commercial agriculture.

The second epoch (1930-1963), the restrictions on African land ownership and participation in commercial agricultural economy were reduced giving rise to increased interaction between agricultural and pastoral communities (Campbell *et al.*, 2003). Consequently, farming communities started settling in areas previously used by pastoralists for dry season grazing (Kitching, 1980). The last epoch covers post-independence, and the policy encouraged diversification of land use in ASALs through expropriation of pastoral areas for wildlife conservation, a move that placed further restrictions on pastoral mobility. As far as late 1970's, it was recognized that these land use changes had ignored the need to support the pastoralists to adopt to the changing conditions.

In the past decade, pastoral areas have recorded rising human population, which mean more livestock to support their livelihoods. However, there are no enough resources to sustain the livestock as pastureland has been converted to farms and settlements. Further, recurrent drought has decimated the livestock population and forced communities to explore alternative livelihoods. The livelihood diversification process being witnessed in the area is driven by ‘pull’ and ‘push’ factors. The push factors aim to minimize the risks driving vulnerability to enhance survival. The pull factors on the other are strategic and aimed at taking advantage of opportunities of complementarity of different activities (Barnett e*t al*., 2001). In both cases, the process reflects voluntary exchange of assets and their allocation of assets across various livelihood activities.

Drought is expected to worsen the ecological conditions and would limit diversification options on land-based resources such as farming. Although risk aversion is an important reason why herders diversify their livelihood, it is not the only one. The reasons causing diversification are multifaceted and can be reduced to a simple explanation (Smith *et al*., 2001). Even among same society, wealthy and poor households diversify for different reasons - the former trying to capitalize on associated opportunities while the latter seeking to survive. As such, the drought mitigations may not have equal weight for the two groups. Diversification may not be a panacea to the drought risks among pastoralists. Studies have shown that if not carefully planned, some adaptation strategies may amplify the risks through maladaptation (Little, 2001).

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The study set out to address three objectives. The first objective was to analyse the relationship between vegetation greenness and drought in Oltiasika area using vegetation and drought indices. The second objective was to examine the biophysical changes taking place in the study area and assess their effects on pastoral livelihood. The third objective was to examine the extent to which pastoral communities have diversified their livelihood system and its impact on household resilience. This chapter gives a summary of the main findings, draws some conclusions and recommendations arising from the findings highlight areas of further research.

5.2 Summary of Results

The study found out that between 1983-2014, the 145 months were categorized as drought based on their Standardized Precipitating Index (SPI). Months with severe drought (SPI value between -1.50 and -1.99) were the most common (69 months) followed by mild drought (SPI ranging between -1.00 and -1.49) in 57 months, while extreme drought (SPI less than -2.00) occurred in 19 months. The study further showed that the period before 1999, extreme droughts used to recur on average every 3.75 years, but increased in frequency to an average of every 1.4 years in the years thereafter pointing to a reduction in the drought cycle. The SPI trend line for the period yielded a positive value (0.0006) suggesting an increase in drought in the area.

The results for the vegetation greenness for the period 2000-2014 produced Normalized Vegetation Difference Index (NDVI) with a mean of 0.3371, which is below the normal conditions mean (0.5). The driest period in the area was observed in September 2004 when the NDVI value was 0.193, while the highest was in December 2006 with an NDVI value of 0.620. The worst drought in the area was recorded in

2009, which had 4 out of 10 months with the worst vegetation conditions. During this year, the average NDVI value was 0.265. A cross seasons, the results showed that before 2006, the value of NDVI for NDJ were higher than for MA, but the situation changed in the years thereafter. This suggests that the MA season had started getting greener as the NDJ season became drier. Further, the study demonstrated a significant statistical relationship between NVDI and SPI, which had an R^2 of 59.6%. Results of the regression analysis between the two variables revealed that vegetation conditions responded positively to drought with a lag of two months.

Objective two of the study was to examine the biophysical changes taking place in the study area and assess their effects on pastoral livelihood. The study established that the area had experienced major land use changes during the period 2011 and 2016. The area under cultivation increased from 7.56 ha to 61.07 ha representing a 707 % change. Most of the farming was practiced by non-Maasai who either leased the land or entered into an agreement with the landowners to share the produces. The main crops grown in the were tomatoes, vegetables, maize, beans and onions most of which were sold in Mombasa and Nairobi cities.

During the same period, the number of settlements had increased in the area and there was a tendency towards modern structures from the traditional Manyattas. While there were 16 Manyattas in the sampled site, the number increased to 25 in 2016 representing a 37.5 percentage change. Furthermore, it was found that the area was increasingly becoming urbanized with the expansion of market centres.

The land use changes resulting from expansion in farming and shift towards sedentary were limiting the flexibility and mobility of livestock within the study area, particularly during drought. As a result, there were declined pasture to support pastoral livelihood. The Gazettement of Chyulu Hills as a protected area in 1983 further denied the pastoralists a critical dry season grassing area.

The third objective of the study was to examine the extent to which pastoral communities have diversified their livelihood system and its impact on household resilience. It was found that communities living in the Oltiasika area had three main sources of income. Income from livestock was the main one accounting for 76% of total household income) followed by crop farming (20%) and non-farm activities (4%). A livelihood diversification index (HHD) for the sampled population showed that majority of respondents (51.14%) had not diversified their livelihood at all. A small proportion (22.73%) had a diversification index of less than 0.25 and this reduced further to 2.84% for respondents whose diversification index was more than 0.5.

The study found that the household resilience to drought decreased with age, household size, while education, total assets and net non-farm income were found to have little effect on household resilience. Livelihood diversification was found to increase the likelihood of increasing household resilience to drought.

5.3 Conclusions

This study has demonstrated that drought continues posing a major challenge for pastoralists in Oltiasika area. While the trend in monthly rainfall was rising, the drought has become more frequent and severe in the area. These changes have adverse effects of natural resources upon which pastoralists depend. Drought index and vegetation conditions were found to be highly correlated. The results of the vegetation response to drought means that NDVI could be a useful tool in monitoring pasture availability and in the design of adaptation measures.

Initially the area was established as a group ranch, with land rights commonly held by the members. The livestock could move within the area in search of pasture and water under the dictates of the pasture availability. Such mobility was an important adaptation strategy in the management of recurrent droughts. This study established that the area was experiencing a transformation as new land uses were being introduced in the area. Analysis of the google earth images confirmed that discernible changes in the land use picked up in earnest in the period after 2011. More land was being cultivated although the type of ‘chance farming’ was the main feature whereby land was cultivated for short period before abandonment. Increasing number of Manyattas was reason for land use change in the area. This was due to rising population of pastoral communities and migration of other communities. Land use changes have implications on the pasture availability and obstructs mobility of livestock across the landscape.

While this study may not offer new insights into the problem of drought and pastoralism, for the first time it has demonstrated the use of multiple methods to understand the implication of drought on biophysical and social systems in pastoral ecosystems.

It is can be concluded that drought alone is not fully responsible for the losses associated with droughts mong pastoralists. Instead, the combined effect of drought and land use changes means that the traditional strategies used to cope with such drought are increasingly compromised and no longer reliable.

Within the Sustainable Livelihood Framework, a livelihood is considered sustainable when it can cope with and recover from stresses and shocks maintain or enhance its capabilities and assets, while not undermining the natural resource base (Chambers and Conway, 1992). Traditional mobility within the pastoralist system is compromised by declining access to rangeland resources. A number of factors are responsible for biophysical changes in pastoral system, including the alienation of pastoral land, the conversion of wet season pasture to other land uses and conflict and insecurity, which have rendered some areas inaccessible (Eneyew, 2012). While crop farming may provide answers to the immediate challenge confronting the Maasai community, the prevailing cultural and physical limitations makes this livelihood an ecologically destructive system. Conversion of pastureland constrain application of a livestock management whereby numbers rather than the quality of the animals is the overriding objective.

Another stress factor for pastoralist in Oltiasika relate to the type of management practised within the study area where the number of livestock is not limited, while natural resource declines. This leads to what is referred to as the tragedy-of-the-commons thesis, postulated by Garret Hardin's. According to Hardin (1968), the tragedy of the commons develops in this way.

> "Picture a pasture opens to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons…. As a rational being, each herdsman seeks to maximize his gain…. The rational herdsman concludes that the only sensible course for him to pursue is to add another animal…and another; and another…. However, this is the conclusion reached by each rational herdsman sharing the common resource. Therein is the tragedy. Each man is locked into a system, which compels him to increase his herd without limit—in a world that is limited. Ruin is the destination towards which all men rush, each pursuing his own interest in a society that believes in the freedom of the commons. Freedom in commons brings ruin to all" (Hardin, 1968:1244).

Mobile pastoralism constitutes a rational use of dryland environments, but this livelihood is undermined by lack of access to basic services, inappropriate policies on land use and repeated humanitarian responses to emergencies (responses that fail to address root causes and structural issues).

Government policies and practices have failed to offer alternative livelihoods to transform pastoralists. This entrenches the practice of stocking large herds designed to ensure that at least some animals survive drought deaths and providing safety against abject poverty. Thus, the pastoralists' tragedy of the commons is fuelled by nature and government neglect.

Pressures on resources in arid and semi-arid areas have been growing in recent years because of human and livestock population growth and at the same time loss of land and water resources to other uses (agriculture, forestry, wildlife reserves). In general, land-use systems increasingly make use of available natural resources during non-drought times reserving few resources for use during drought.

Overall, it can be inferred that although majority of households were dependent on livestock as their primary livelihood, the proportion of income generated by other activities represents a substantial component of earnings. For pastoralists, use of wetter areas and water sources by farming communities, coupled with the loss of dry season grazing land to Chyulu National Parks, has increased their vulnerability to ecological change and drought. However, the pastoralists were found to possess very few livelihood diversification options. After the drought of 2009, communities in Oltiasika area have not restocked their livelihood to levels before the drought.

Adoption of crop farming was found to enhance household's reliance on food security. However, this is only in the short term. Taken together with the environmental conditions of the area, crop farming would further make it increasingly difficult for households to eke a living as chance farming is likely further reduce available pasture resources.

5.4 Recommendations

The study demonstrated that drought working and land use experienced in Oltiasika area are the main drivers of change among pastoral communities. In order to secure the future of the pastoralists, this study makes the following recommendations.

1. Land use changes taking place in the study area needs to be reviewed to ensure they are not a threat to pastoral mobility. Spatial planning should be undertaken in the area to guide crop production and settlement so that new livelihood activities can co exit with pastoralism.

2. To cope with drought, there is need to intensify assessment of its occurrence and impacts for purposes of designing and implementing contingency measures. The two months lag period between drought and vegetation health found in this study should provide critical information to guide pasture and fodder management practices as well as livestock restocking programmes.

3. Any adaptation strategies should seek to enhance rather than threaten pastoralism. Responding to climate change will require deliberate planned approaches to provide the investments necessary for appropriate and sustainable development, allowing pastoralists either to adapt to their changing environment, or to transition out of pastoralism into alternative livelihoods. In order to realise the economic potential of pastoralism and achieve projected growth in livestock sectors, governments will have to invest in pastoral production systems. An initial and vital step in this process will be adapting livestock and disease control policies to boost commercialization of pastoralism. For those continuing with pastoralism as well as those who have abandoned the practice, various forms of social protection will be essential.

Shift to crop cultivation through important in increasing household food resilience should be a temporary measure to enable pastoralists recover from drought and restock.

5.5 Recommendation for Future Research

This study has for the first time provided preliminary results linking drought effects on biophysical conditions to community resilience. Biophysical effects were confined to vegetation, without including other resources such as water which are critical important for pastoralism. Further work incorporating all aspects of biophysical environment will be important in gaining a holistic understanding of the effects of drought.

Recent literature on resilience measurement conceptualize it as dynamic rather than static as used in the current study. To gain a full understanding of changes in resilience due to drought, further research should aim to analyse resilience by using data collected over a long period prior to and after a drought event.

Further research should also be directed to understanding the effects of ranch subdivisions in the Chyulu-Amboseli ecosystem on livelihood diversification. Such studies should be framed to quantify individual contributions to drought and land use change on livelihood diversification.

Finally, it will be important to carry out further research to examine alternative livelihoods options in pastoral area to ensure that they contribute to the wellbeing of the affected communities without compromising the environment.

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Appendix 1: Household Questionnaire

Questionnaire No [ ]

Kenyatta University Student Survey Instrument

_______________________________is conducting this survey on behalf of Mr. John Nangana, a student at Kenyatta University The survey is part of the research requirements for the award of a Doctor of Philosophy (PhD) degree. The objective of this research is to **investigate livelihood diversification as a drought management strategy in Oltiasika Area, Kajiado County**. I am collecting information from households, government officials, and researchers in order to understand the relationship between drought, pasture availability, land use change, coping strategies and related variables. You have been randomly selected to participate in this survey, and I kindly request you to answer the following questions as appropriate. All data and information collected will be treated with utmost confidentiality and used exclusively for academic purposes. Your response to this questionnaire will be highly appreciated.

1. **GENERAL INFORMATION**

Date of interview _________________

Sub-Location___________________

GPS Number [ ]

HH Elevation m. a.s.l		Gender of Respondent 1 M 0 F	
GPS =S (hd*mm'ss.s")		Age of Respondent (Yrs)	
GPS =E		Relationship of respondent to household head	

2 HOUSEHOLD SOCIO ECONOMIC CHARACTERISTICS

2.1 Household type (Select only one)

1 = Male headed and managed ; 2 =Male headed, female managed (wife makes most household decisions);

3 =Female headed and managed; 4 = Child headed (age 16 or under)/Orphan [ ]

2.1.2 What is the highest level of education completed by the household head?

0= no formal education; 1 =primary school, 2= secondary school; 3 =tertiary education [ ]

2.1.3 What is the primary occupation of the household head?

0= livestock farming, 1= crop farming, 2 =business, 3= salary employment [ ]

2.1.4. Time taken to the nearest tarmac road. 0-30min [ ] 30-60min [ ] more than 60 min [ ]

2.2 House characteristics

2.2.1 How many people live and usually take meals together in your household? [ ]

2.2.2 What is the type of material used in your main house?

		Tick one				
Indicate type of Flooring materials	Earth sand	Dung	Ceramic	Cement	Carpet	Other
	1	2	3	4	5	6

2.4 Household assets

What are the current values of the assets owned by household? (**Provide estimates of total assets owned)**

Assets	Current Total	Asset	Current Total
1- houses		14- weighing machine	
2 -stores		15- cattle dip	
3 -water tanks		16--irrigation equipment/pipes	
4 -radio		17-water pump	
5 -TV		18-truck/lorry/tractor/ car	
6 -telephone/mobile		19-generator	
7 -solar panels		20-Green house	
8-motorcycle		21- Computer /Lap-top	
9-gas cooker		22- Furniture (total)	
10-bicycle		23-poultry houses	
11-wheel barrow		24-borehole	
12-water trough		25- Others	
13- dam			

2.5 Sources and levels of household income

Provide information on income from **off-farm** and **non-farm** activities in the last past year

	Off-Farm income activity – define off-farm- not related to your farm	*Did your household receive income from this activity in the past 12 months? 1=YES; 0= NO*	*Amount received (KES)*
01	*Salaried employment (household head)*		
02	*Salaried employment (spouse)*		
03	*Pension Income*		
04	*Farm labour wages (household head and spouse)*		

05	*Non-farm labour wages (household head and spouse)*		
07	*Business NET income (shops, trade, tailor, brewing etc.)*		
08	*Amount received from children within household (employment or off-farm income)*		
09	*Remittances (from relatives from outside household)*		
10	*Sales of off-farm products (charcoal, bricks, sand, baskets, kiondos etc)*		
11	*Renting out land*		
12	*Renting out equipment/machinery*		
	Other 1 (specify): ______________		

3 LAND TENURE AND LAND USE CHARACTERISTICS

3.1 How many parcels of land are **owned** by the household?

3.2 How many parcels of land are **accessed/used** by the household?

3.3 For each of the land parcels, give the following information:

(In this section, we collect information about the land that the Household head or his/her spouse owns and/or uses).

	Land 00 (Homestead)	Land 01 (within oltiasika)	Land 02 (outside oltiasika)
Size (acres)			
How far from the homestead (km)?	0		
What is the land tenure type for this parcel? (1 private, 2 communal, 3 other)			
Who currently uses that parcel of land? (1 self, 2 leasesd, 3 fallow, 4 other)			
How is the land allocated to the following different uses			

(*specify area and give units*)			
1. Homestead			
2. Livestock Production (Improved pastures/forages production)			
3 Crop production			
4. Natural pastures			
5. Unusable land (swampy, rocky, hilly, e.t.c)			

3.4 How many years have you lived in Mbirikani? [ ]

4 LIVESTOCK PRODUCTIONS

4.1 Do you keep livestock? 0= No 1= Yes [ ] (if No, go to 5), If yes, provide the details required below

Category of livestock	Number of animals owned currently	Number of animals owned 10 years ago	Cost of herding KES/ month	Cost of veterinary services (KES/ month)	Other costs (minerals etc)
Cattle					
Goats/sheep					
Chicken					

4.2 Give details for milk production in the last 12 months (fill only if any of the 3-priority livestock is a milk producer)

Livestock species	Season	Milk/animal/day (litre)	Lactation duration (months)	Amount consumed at home per month (Litres)	Amount sold month	Price per litre KES

					(litre)	
Cattle	Dry season					
	Wet season					
Goat/sheep	Dry season					
	Wet season					

5. CROP PRODUCTION

5.1 Do you produce any crops? 1= Yes, 0 =No [ ] (if No, go to 6)

5.2 If yes, for how long (years) have you been growing crops on your farm?________________

Provide the following details for the main crops grown

Crops grown	Size (acres)	Cost of land/KES month	Cost of labour KES/month	Cost of Seeds KES	Cost of water month KES	Cost of fertilizer KES	Quantity harvested (indicate units)	Price per unit KES

5.3 Do you use earnings obtained from crops for livestock purposes? 1 =Yes, 0 =No [ ]

If yes, which one?

Livestock purpose	Indicate appropriate no
1 Purchase of livestock	
2 Purchase of fodder	
3 Payment of causal labor	
4 Purchase of livestock veterinary services	

6 CLIMATE CHANGE AND ADAPTATION

6.1 What was the main livelihood type 10 years ago? 1 livestock, 2 crops, 3 mixed farming, 4 non-farming activities [ ]

6.2 Have you experienced any climate change in this area? 1=Yes 0=No [ ]

6.3 If yes, which changes have you noticed? 0=More rainfall, 1=less rainfall, 2= increasing temperature, 3= decreasing temperature

6.4. Which year did you experience the worst drought? Year [ ]

6.4 What was the nature of climate impact? 1= drought, 2= flood [ ]

6.5 In what ways did the change in 6.4 above affect you?

Climate change effects	Indicate appropriate No.	Climate change effects	Indicate appropriate No.
1 Loss of crop		3 Livestock deaths	
2 Livestock diseases		4 Declining water resources	

6.6 In case of livestock death during the worst drought year please provide the following information

Type of livestock	No. of livestock before drought	No. of livestock after climate drought
Cattle		
Goats		
Sheep		

6.7 Have you taken any action to respond to climate change? 1 =yes, 0 No= [ ],

If yes, what actions have you taken to address climate change?

Adaptation strategies	*Indicate appropriate No.*	Adaptation strategies	*Indicate appropriate No.*
1 Soil and water conservation		6 fodder management /paddocking	
2 Irrigation		7 Shift to crop farming	
3 Tree planting		8 Shift to livestock farming	
4 Changes in crop variety		9 Shift to non-farming activities	
5 Reduced number of livestock		10 Others: (specify) ___________________________	

6.8 If you do irrigation, what is the source of the water? 0=swamp spring, 1= dam, 2 =pipe line [ ]

7 In the last 12 months, were there months you did not have enough food to meet the needs of your family? 1=Yes, 0= No [ ]

If yes, indicate the months when you did not have enough food.

Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Total no. of months
[__	[__]	[__]	[__	[__]	[__	[__]	[__]	[__]	[__]	[__]	[__]	[__ __]

END

Appendix 2: Focus Group Discussion Guide

My name is John Nyangena, a student at Kenyatta University. I am conducting research as part of the requirements for the award of a Doctor of Philosophy (PhD) degree in Environmental Planning and Management. The objective of this research is to investigate livelihood diversification as a drought management strategy in the Chyulu-Amboseli Ecosystem, Kajiado County. You were selected to participate in this research because of knowledge and experience of drought and livelihood in this area. The information collected will be treated with utmost confidentiality and used exclusively for academic purposes. My role will be to moderate the discussions but before we start, I request for your permission to record the proceedings for future reference.

Number of participants ………………………………

Venue………………………………………………….

Start time………………………………………………

End time……………………………………………….

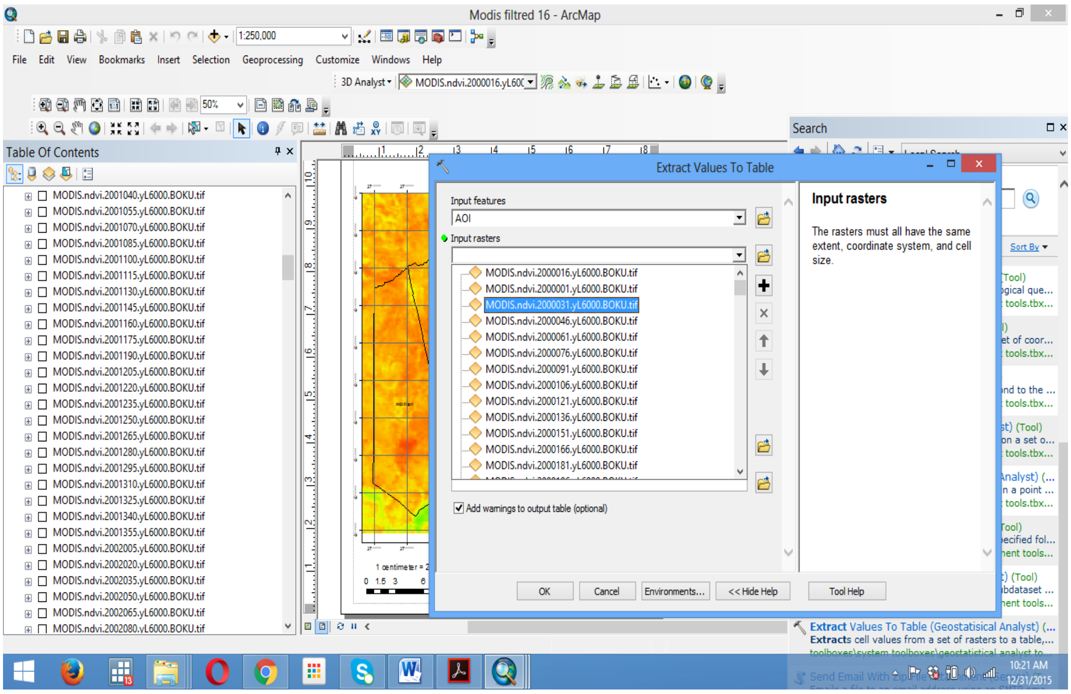
1. I will like us to agree on the rule to guide our discussions.
2. Tell me about the history of this place in terms of settlement
3. Describe how people in your area used to derive livelihood and how this has changed over time.
4. How can you describe drought conditions in your area, its occurrence, severity and effects?
5. When did you experience drought in this area and what was the effect on livestock population?
6. Apart from drought what other factors influence pastoralism in your area?
7. What are the main strategies employed by pastoralists to reduce the effects of drought? How have these changed over time?
8. How important is pastoralism as a source of livelihood compared to ten years ago?
9. Which alternative livelihoods have emerged in this past 10 years?
10. What is the future of pastoralism under changing drought?

Appendix 3: Key Informant Interview Guide

My name is John Nyangena, a student at Kenyatta University. I am conducting research as part of the requirements for the award of a Doctor of Philosophy (PhD) degree in Environmental Planning and Management. The objective of this research is to investigate livelihood diversification as a drought management strategy in the Chyulu-Amboseli Ecosystem, Kajiado County. You were selected to participate in this research because of knowledge and experience of drought and livelihood in this area. The information collected will be treated with utmost confidentiality and used exclusively for academic purposes. My role will be to moderate the discussions but be we start, I request for your permission to record the proceedings for future reference.

1. What are the main climatic changes observed in this area
2. How have these changes affected the vegetation conditions in this area?
3. In what ways have changes in vegetation affected livelihood activities in Oltiasika area?
4. Apart from climate changes, what other changes have you observed, and how have these influenced livelihood activities in the area?
5. How have pastoralists adjusted their livelihoods to these changes?
6. How effective are these adjustments given the changing climate?
7. How does response to climate change vary across households?
8. To what extent do changes in livelihood contribute to household ability to cope to drought?
9. In what ways can pastoralism continue as an important livelihood activity in coming years?
10. What are your views on the sustainability of different livelihood activities practiced in Oltiasika area?

Appendix 4: Extraction of Normalized Difference Vegetation Index values to Tables in ArcGIS



Appendix 5: Rainfall data Extracted from Sultan Hamud Station No. 9237049

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1979	35.616	36.164	74.007	32.894	10.607	2.987	6.266	14.450	3.403	4.012	15.821	48.241
1980	14.682	3.746	2.542	11.380	10.103	3.308	1.453	8.885	7.260	3.203	17.366	8.859
1981	3.010	2.940	106.306	54.700	20.149	8.336	5.299	5.498	4.128	1.845	9.108	20.271
1982	11.766	8.850	2.861	32.336	10.130	2.151	6.608	43.158	6.782	6.273	103.309	18.483
1983	5.396	22.177	14.835	27.650	26.377	9.859	43.530	10.712	10.525	11.404	16.010	42.448
1984	117.808	0.745	4.607	31.347	23.514	3.201	8.293	16.088	11.585	16.933	76.929	40.568
1985	7.232	12.883	25.553	31.280	17.958	3.747	4.310	2.687	4.887	4.764	32.211	50.168
1986	4.249	5.234	0.505	22.787	62.413	64.972	4.099	2.956	10.420	9.650	44.380	151.863
1987	10.840	3.407	19.921	48.816	75.452	8.368	10.919	14.802	11.209	4.511	13.790	14.959
1988	27.396	5.697	69.440	112.689	12.710	7.045	10.921	12.294	7.448	6.128	46.396	77.518
1989	20.603	3.955	17.908	44.931	38.019	5.594	8.231	6.312	8.853	9.433	58.943	67.072
1990	37.868	13.012	47.092	230.167	67.566	14.003	10.902	11.963	11.046	9.143	61.069	66.193
1991	4.724	0.573	5.394	32.360	96.378	64.835	6.494	10.667	8.675	6.681	12.535	77.455
1992	23.942	7.807	2.139	41.065	43.043	30.133	13.335	7.911	15.884	63.758	29.703	36.790
1993	122.447	14.365	14.800	33.783	19.109	6.336	5.868	7.448	5.639	12.057	34.732	18.411
1994	3.469	32.276	41.463	33.376	14.583	3.159	6.171	6.430	8.396	17.921	72.586	33.828
1995	45.869	29.311	24.456	32.175	46.328	11.459	7.138	11.048	6.012	6.990	31.255	36.594
1996	10.030	1.986	41.734	48.037	26.183	16.853	15.075	10.487	19.444	11.868	20.596	57.882
1997	3.608	0.010	1.582	59.374	14.538	18.254	2.966	5.581	8.810	14.103	89.230	149.900
1998	115.269	147.865	26.918	66.514	77.946	18.821	9.075	27.496	13.109	15.425	26.866	10.674
1999	1.397	8.341	54.403	18.109	0.713	1.575	8.315	9.851	4.961	69.753	51.492	37.366
2000	0.797	6.448	23.161	7.988	1.878	7.405	4.752	10.302	7.615	9.542	64.716	92.049
2001	60.084	17.365	18.651	10.689	3.706	4.996	10.305	12.519	8.209	26.286	31.879	45.676

2002	13.348	67.648	11.419	92.241	38.622	4.918	4.486	8.862	4.554	19.310	31.635	60.030
2003	5.495	1.775	16.528	10.478	94.685	4.678	4.679	12.622	5.972	11.986	50.812	42.960
2004	26.123	24.513	3.153	20.503	21.209	2.074	6.875	6.175	11.472	17.618	133.213	3.529
2005	7.102	10.386	88.297	13.595	9.907	6.624	16.457	10.258	4.674	17.232	102.990	12.281
2006	35.948	72.376	16.792	64.208	1.828	8.841	10.778	9.580	5.836	53.818	91.422	112.042
2007	12.613	3.554	20.136	65.697	29.078	6.822	5.362	9.398	12.432	19.858	57.368	51.226
2008	45.558	9.824	118.309	43.791	1.260	11.366	16.176	10.855	2.905	10.176	92.357	23.406
2009	38.844	14.842	14.766	34.327	18.666	2.525	2.141	13.760	5.025	11.070	23.272	65.020
2010	13.234	64.428	93.835	61.942	6.604	4.467	9.238	16.016	4.247	45.985	50.189	32.463
2011	138.028	59.175	154.397	125.577	10.693	15.602	30.161	13.330	26.995	92.718	174.453	35.038
2012	4.022	40.028	63.091	187.612	28.695	10.794	7.946	11.077	3.946	109.350	137.619	101.999
2013	91.368	31.508	196.813	368.071	15.759	10.497	9.586	9.821	7.270	26.613	140.863	217.280
2014	14.902	220.369	179.132	123.965	66.726	8.558	13.631	17.844	125.387	29.242	33.505	27.831
2015	26.529	38.100	175.711	149.671	77.120	59.925	4.536	37.978	45.707	38.391	14.865	32.232
2016	22.345	35.592	94.120	128.405	33.162	3.363	9.305	78.892	55.226			

Appendix 6: Standardized Precipitation Index using data from Sultan Hamud Station No. 9237049

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1979	0.19	0.21	1.44	0.07	-1.34	-2.49	-1.86	-1.00	-2.38	-2.25	-0.89	0.67
1980	-0.98	-2.31	-2.61	-1.26	-1.39	-2.41	-3.02	-1.52	-1.72	-2.43	-0.78	-1.52
1981	-2.48	-2.50	2.20	0.88	-0.60	-1.58	-2.01	-1.98	-2.23	-2.85	-1.49	-0.59
1982	-1.23	-1.52	-2.52	0.04	-1.39	-2.74	-1.81	0.49	-1.78	-1.86	2.13	-0.71
1983	-1.99	-0.48	-0.97	-0.18	-0.24	-1.41	0.50	-1.33	-1.35	-1.26	-0.88	0.46
1984	2.43	-3.46	-2.13	0.00	-0.40	-2.43	-1.59	-0.87	-1.24	-0.81	1.52	0.39
1985	-1.72	-1.13	-0.29	-0.01	-0.74	-2.31	-2.19	-2.57	-2.08	-2.10	0.04	0.73
1986	-2.20	-2.02	-3.70	-0.44	1.12	1.19	-2.23	-2.50	-1.36	-1.44	0.53	3.05
1987	-1.31	-2.38	-0.61	0.69	1.48	-1.58	-1.31	-0.97	-1.28	-2.15	-1.05	-0.96
1988	-0.19	-1.94	1.32	2.33	-1.14	-1.75	-1.31	-1.18	-1.69	-1.88	0.60	1.53
1989	-0.57	-2.26	-0.74	0.55	0.29	-1.96	-1.60	-1.85	-1.52	-1.46	1.01	1.25
1990	0.28	-1.12	0.63	4.22	1.27	-1.03	-1.31	-1.21	-1.29	-1.49	1.08	1.23
1991	-2.11	-3.62	-1.99	0.04	1.98	1.19	-1.82	-1.33	-1.54	-1.80	-1.16	1.53
1992	-0.38	-1.65	-2.74	0.41	0.48	-0.06	-1.09	-1.63	-0.89	1.16	-0.08	0.24
1993	2.52	-1.00	-0.97	0.11	-0.66	-1.85	-1.92	-1.69	-1.95	-1.20	0.15	-0.71
1994	-2.37	0.04	0.42	0.09	-0.99	-2.44	-1.87	-1.83	-1.58	-0.74	1.40	0.11
1995	0.58	-0.10	-0.35	0.04	0.60	-1.26	-1.73	-1.29	-1.89	-1.75	-0.01	0.23
1996	-1.40	-2.80	0.43	0.66	-0.26	-0.82	-0.95	-1.35	-0.64	-1.22	-0.57	0.98
1997	-2.34	-4.61	-2.96	1.03	-0.99	-0.72	-2.49	-1.96	-1.53	-1.03	1.82	3.02
1998	2.38	2.99	-0.22	1.24	1.54	-0.68	-1.50	-0.19	-1.11	-0.92	-0.22	-1.33
1999	-3.05	-1.58	0.87	-0.73	-3.49	-2.97	-1.59	-1.41	-2.07	1.33	0.78	0.26
2000	-3.42	-1.83	-0.42	-1.63	-2.84	-1.70	-2.10	-1.37	-1.67	-1.45	1.18	1.88
2001	1.05	-0.78	-0.69	-1.33	-2.32	-2.06	-1.37	-1.16	-1.60	-0.25	0.02	0.58
2002	-1.09	1.27	-1.26	1.89	0.31	-2.07	-2.15	-1.52	-2.14	-0.65	0.01	1.05
2003	-1.98	-2.88	-0.84	-1.35	1.94	-2.12	-2.12	-1.15	-1.90	-1.21	0.76	0.48

2004	-0.26	-0.34	-2.45	-0.58	-0.53	-2.77	-1.77	-1.87	-1.25	-0.76	2.72	-2.36
2005	-1.74	-1.36	1.80	-1.07	-1.41	-1.80	-0.85	-1.37	-2.12	-0.79	2.13	-1.18
2006	0.20	1.40	-0.82	1.17	-2.86	-1.52	-1.32	-1.44	-1.92	0.85	1.87	2.32
2007	-1.15	-2.35	-0.60	1.21	-0.11	-1.78	-2.00	-1.46	-1.17	-0.62	0.97	0.77
2008	0.57	-1.42	2.44	0.51	-3.12	-1.26	-0.87	-1.31	-2.51	-1.38	1.89	-0.41
2009	0.32	-0.97	-0.97	0.13	-0.69	-2.62	-2.74	-1.05	-2.06	-1.29	-0.41	1.19
2010	-1.10	1.18	1.92	1.10	-1.81	-2.16	-1.48	-0.88	-2.20	0.59	0.73	0.05
2011	2.81	1.02	3.10	2.58	-1.33	-0.91	-0.06	-1.09	-0.21	1.90	3.42	0.16
2012	-2.25	0.37	1.14	3.62	-0.13	-1.32	-1.63	-1.29	-2.26	2.26	2.80	2.10
2013	1.87	0.01	3.76	5.82	-0.90	-1.35	-1.44	-1.42	-1.72	-0.23	2.86	4.05
2014	-0.96	4.09	3.49	2.55	1.24	-1.56	-1.06	-0.75	2.58	-0.10	0.09	-0.17
2015	-0.24	0.29	3.44	3.02	1.52	1.04	-2.14	0.28	0.58	0.30	-0.97	0.04
2016	-0.47	0.19	1.93	2.64	0.08	-2.39	-1.47	1.57	0.90			

Appendix 7: Categorization of Drought using SPI, 1983-2014

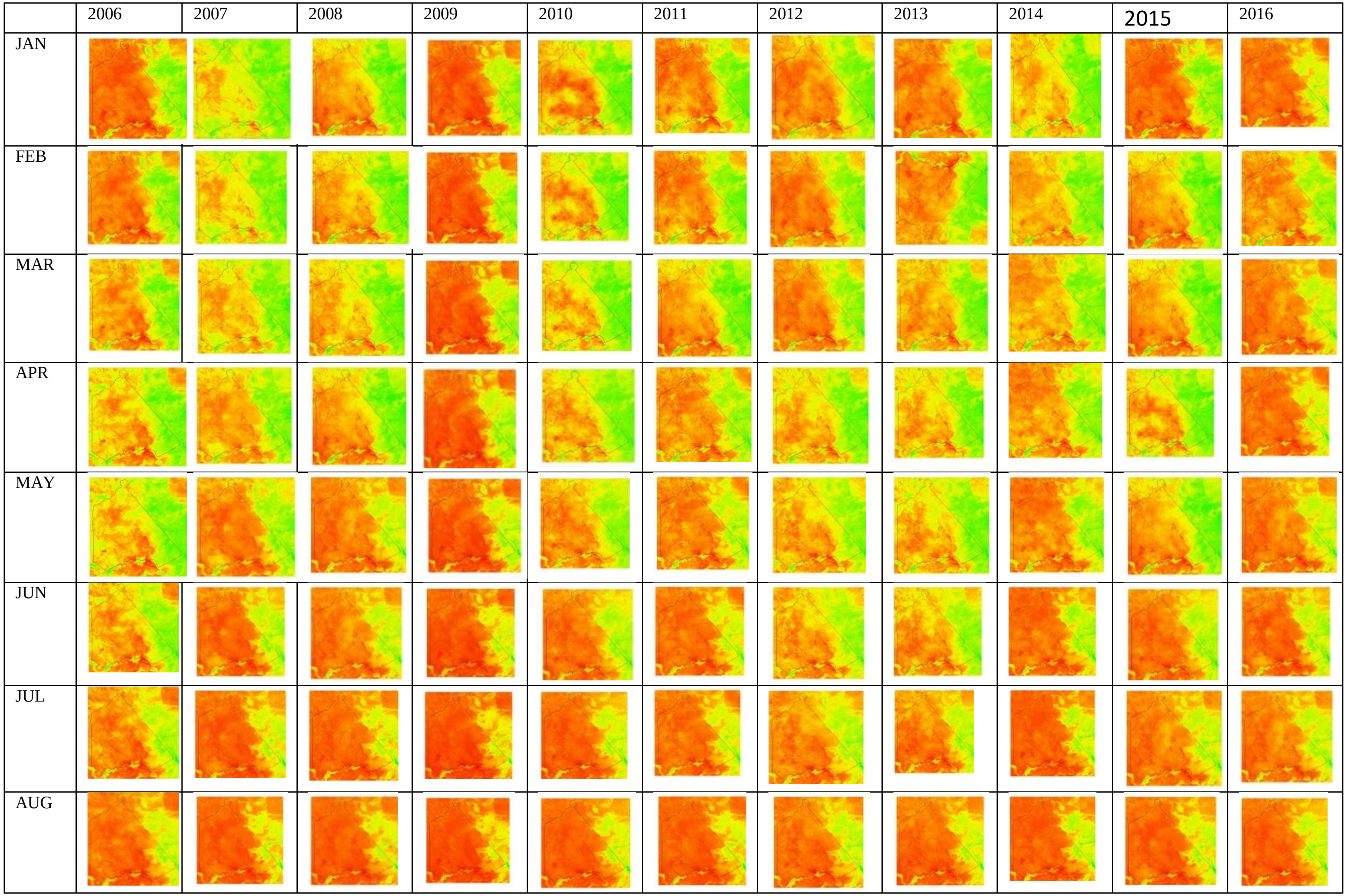
Month	Rainfall	SPI	Mild Drought	Severe Drought	Extreme Drought
May-79	10.607	-1.337	1	0	0
Jun-79	2.987	-2.489	0	1	0
Aug-79	14.450	-0.998	1	0	0
Sep-79	3.403	-2.385	1	0	1
Oct-79	4.012	-2.249	1	0	0
Nov-79	15.821	-0.893	1	0	0
Jan-80	14.682	-0.979	1	0	0
Feb-80	3.746	-2.306	1	0	0
Mar-80	2.542	-2.615	0	1	0
Apr-80	11.380	-1.262	1	0	0
May-80	10.103	-1.388	1	0	0
Jun-80	3.308	-2.408	0	1	0
Jul-80	1.453	-3.022	0	0	1
Aug-80	8.885	-1.520	1	0	0
Sep-80	7.260	-1.718	1	0	0
Oct-80	3.203	-2.434	0	1	0
Nov-80	17.366	-0.782	1	0	0
Dec-80	8.859	-1.523	1	0	0
Jan-81	3.010	-2.483	0	1	0
Feb-81	2.940	-2.502	0	1	0
May-81	20.149	-0.599	1	0	0
Jun-81	8.336	-1.583	1	0	0
Jul-81	5.299	-2.009	1	0	0
Aug-81	5.498	-1.976	1	0	0
Sep-81	4.128	-2.225	1	0	0
Oct-81	1.845	-2.853	0	1	0
Nov-81	9.108	-1.495	1	0	0
Dec-81	20.271	-0.591	1	0	0
Jan-82	11.766	-1.227	1	0	0
Feb-82	8.850	-1.524	1	0	0
Mar-82	2.861	-2.523	0	1	0
May-82	10.130	-1.385	1	0	0
Jun-82	2.151	-2.741	0	1	0
Jul-82	6.608	-1.807	1	0	0
Sep-82	6.782	-1.783	1	0	0
Oct-82	6.273	-1.856	1	0	0
Dec-82	18.483	-0.706	1	0	0
Jan-83	5.396	-1.993	1	0	0
Feb-84	0.745	-3.461	0	0	1
Mar-84	4.607	-2.132	1	0	0
Jun-84	3.201	-2.434	0	1	0

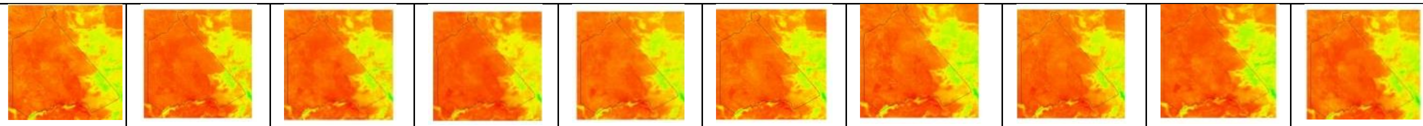
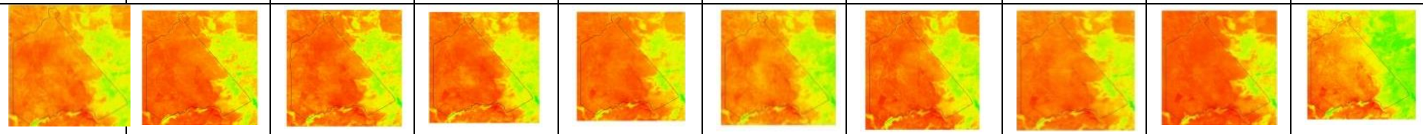
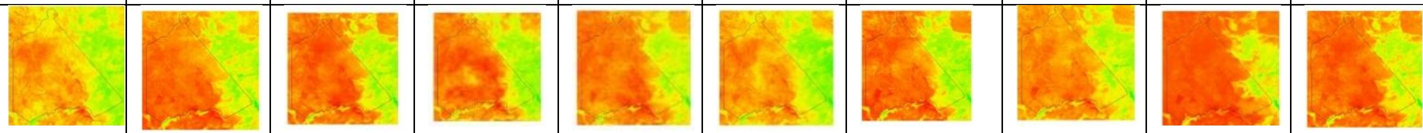
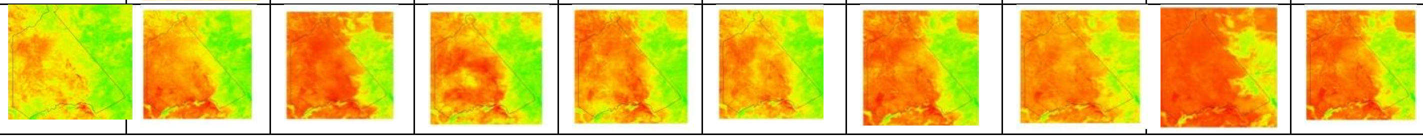
Jan-85	7.232	-1.722	1	0	0
Jun-85	3.747	-2.306	1	0	0
Jul-85	4.310	-2.189	1	0	0
Aug-85	2.687	-2.572	0	1	0
Sep-85	4.887	-2.080	1	0	0
Oct-85	4.764	-2.103	1	0	0
Jan-86	4.249	-2.201	1	0	0
Feb-86	5.234	-2.020	1	0	0
Mar-86	0.505	-3.698	0	0	1
Jul-86	4.099	-2.231	1	0	0
Aug-86	2.956	-2.498	0	1	0
Feb-87	3.407	-2.384	0	1	0
Oct-87	4.511	-2.150	1	0	0
Feb-88	5.697	-1.944	1	0	0
Jun-88	7.045	-1.747	1	0	0
Sep-88	7.448	-1.693	1	0	0
Oct-88	6.128	-1.877	1	0	0
Feb-89	3.955	-2.261	1	0	0
Jun-89	5.594	-1.960	1	0	0
Aug-89	6.312	-1.850	1	0	0
Jan-91	4.724	-2.110	1	0	0
Feb-91	0.573	-3.622	0	0	1
Mar-91	5.394	-1.993	1	0	0
Jul-91	6.494	-1.823	1	0	0
Oct-91	6.681	-1.797	1	0	0
Mar-92	2.139	-2.745	0	1	0
Jun-93	6.336	-1.846	1	0	0
Jul-93	5.868	-1.917	1	0	0
Aug-93	7.448	-1.693	1	0	0
Sep-93	5.639	-1.953	1	0	0
Jan-94	3.469	-2.369	0	1	0
Jun-94	3.159	-2.445	0	1	0
Jul-94	6.171	-1.871	1	0	0
Aug-94	6.430	-1.833	1	0	0
Jul-95	7.138	-1.734	1	0	0
Sep-95	6.012	-1.895	1	0	0
Oct-95	6.990	-1.754	1	0	0
Feb-96	1.986	-2.799	0	1	0
Jan-97	3.608	-2.337	1	0	0
Mar-97	1.582	-2.963	0	1	0
Jul-97	2.966	-2.495	0	1	0
Aug-97	5.581	-1.962	1	0	0
Jan-99	1.397	-3.049	0	0	1
May-99	0.713	-3.489	0	0	1

Jun-99	1.575	-2.966	0	1	0
Sep-99	4.961	-2.067	1	0	0
Jan-00	0.797	-3.419	0	0	1
Feb-00	6.448	-1.830	1	0	0
May-00	1.878	-2.840	0	1	0
Jun-00	7.405	-1.699	1	0	0
Jul-00	4.752	-2.105	1	0	0
May-01	3.706	-2.315	1	0	0
Jun-01	4.996	-2.061	1	0	0
Jun-02	4.918	-2.075	1	0	0
Jul-02	4.486	-2.155	1	0	0
Sep-02	4.554	-2.142	1	0	0
Jan-03	5.495	-1.976	1	0	0
Feb-03	1.775	-2.881	0	1	0
Jun-03	4.678	-2.118	1	0	0
Jul-03	4.679	-2.118	1	0	0
Sep-03	5.972	-1.901	1	0	0
Mar-04	3.153	-2.446	0	1	0
Jun-04	2.074	-2.768	0	0	0
Jul-04	6.875	-1.770	1	0	0
Aug-04	6.175	-1.870	1	0	0
Dec-04	3.529	-2.355	0	1	0
Jan-05	7.102	-1.739	1	0	0
Jun-05	6.624	-1.805	1	0	0
Sep-05	4.674	-2.119	1	0	0
May-06	1.828	-2.860	0	1	0
Sep-06	5.836	-1.922	1	0	0
Feb-07	3.554	-2.350	1	0	0
Jun-07	6.822	-1.777	1	0	0
Jul-07	5.362	-1.998	1	0	0
May-08	1.260	-3.120	0	0	1
Sep-08	2.905	-2.511	0	1	0
Jun-09	2.525	-2.620	0	1	0
Jul-09	2.141	-2.744	0	1	0
Sep-09	5.025	-2.056	1	0	0
May-10	6.604	-1.808	1	0	0
Jun-10	4.467	-2.158	1	0	0
Sep-10	4.247	-2.201	1	0	0
Jan-12	4.022	-2.247	1	0	0
Sep-12	3.946	-2.263	1	0	0
Sep-13	7.270	-1.717	1	0	0
Jun-14	8.558	-1.557	0	1	0
Jul-14	13.631	-1.064	1	0	0
Aug-14	17.844	-0.749	1	0	0

Jul-15	4.536	-2.145	0	0	1
Nov-15	14.865	-0.965	1	0	0
Jan-16	22.345	-0.466	1	0	0
Jun-16	3.363	-2.395	0	0	1
Jul-16	9.305	-1.473	0	1	0

Appendix 8: Normalized Difference Vegetation Index for Oltiasika, 2006-2016



SEP		
OCT		
NOV		
DEC		

Appendix 9: MODIS Normalized Difference Vegetation Index for Oltiasika

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	0.3234	0.3864	0.4036	0.3103	0.2769	0.2688	0.2374	0.2368	0.3340	0.4902	0.5738	0.4580
2001	0.3655	0.4918	0.3646	0.2734	0.2636	0.2338	0.2289	0.2744	0.4533	0.4941	0.4124	0.3475
2002	0.3992	0.3781	0.2984	0.2609	0.2416	0.2394	0.2315	0.3743	0.5755	0.4790	0.3699	0.2890
2003	0.2850	0.4519	0.3574	0.2685	0.2473	0.2338	0.2892	0.3816	0.3390	0.4803	0.4525	0.4261
2004	0.4206	0.3115	0.2700	0.2390	0.2347	0.2328	0.2172	0.3624	0.3463	0.3014	0.2903	0.4498
2005	0.3584	0.2806	0.2475	0.2252	0.2162	0.2381	0.3492	0.2874	0.2470	0.2711	0.4517	0.5252
2006	0.4172	0.3057	0.2638	0.2369	0.2443	0.3917	0.5739	0.6196	0.5061	0.3677	0.3443	0.3260
2007	0.2812	0.2703	0.2445	0.2463	0.2461	0.3160	0.4137	0.4182	0.3664	0.3624	0.5411	0.3487
2008	0.3025	0.4206	0.3983	0.4307	0.3095	0.3043	0.3132	0.2780	0.2556	0.2448	0.2706	0.2601
2009	0.2463	0.2203	0.2144	0.2014	0.2067	0.2566	0.3819	0.4136	0.3343	0.4849	0.5524	0.4216
2010	0.3180	0.2696	0.2397	0.2312	0.2333	0.3915	0.4315	0.3274	0.3217	0.3754	0.4114	0.3180
2011	0.2539	0.2362	0.2244	0.2211	0.2507	0.5508	0.4060	0.2987	0.2638	0.2897	0.5345	0.4031
2012	0.2931	0.2633	0.2308	0.2215	0.3263	0.3560	0.3959	0.3470	0.2989	0.4582	0.5153	0.3436
2013	0.2922	0.2523	0.2316	0.2308	0.2432	0.4547	0.4918	0.3399	0.4514	0.4679	0.4249	0.3187
2014	0.2600	0.2449										

Appendix 10: Research Permit

THIS IS TO CERTIFY THAT:
MR. JOHN - NYANGENA
of KENYATTA UNIVERSITY, 240-100
Nairobi,has been permitted to conduct
research in *Kajiado County*

on the topic: *LIVELIHOOD DIVERSIFICATION AS A DROUGHT MANAGEMENT STRATEGY IN THE CHYULU-AMBOSELI ECOSYSTEM, KAJIADO COUNTY, KENYA*

for the period ending:
31st March,2015

Permit No : NACOSTI/P/14/1178/2785
Date Of Issue : 19th August,2014
Fee Recieved :Ksh 2,000

Applicant's Signature

for Secretary
National Commission for Science, Technology & Innovation