

**CLIMATE VARIABILITY AND LIVELIHOOD VULNERABILITY
ASSESSMENT OF THE MAASAI PASTORALISTS IN AMBOSELI
ECOSYSTEM, KAJIADO COUNTY, KENYA**

BY

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DECLARATION

This dissertation represents my unique effort and has not been presented for the attainment of a degree or any other recognition at any other educational institution.

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DEDICATION

I dedicate this work to my beloved mother Kiraine Oloitipitip and my children Sintamei, Siano and Sopei together with the people of Amboseli Ecosystem both men and women, who took time to willingly share their experiences on climate variability by actively participating in the data collection process.

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ACCRONYMS AND ABBREVIATIONS

ACTED	Agency for Technical Cooperation and Development
ANP	Amboseli National Park
AR4	Forth Assessment Report
ASALs	Arid and Semi-Arid Lands
CDEs	County Directors of Education
ENSO	El Nino-Southern Oscillation
FAO	Food and Agriculture Organization
FDGs	Focused Group Discussion
GDP	Gross domestic product
GHG	Green House Gases
GOK	Government of Kenya
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
KARI	Kenya Agricultural Research Institute
KMD	Kenya Meteorological Department
KNBS	Kenya National Bureau of Statistics
KNBS	Kenya National Bureau of Statistics
KWS	Kenya Wildlife Service
NACOSTI	National Commission for Science, Technology and Innovation
NCCRS	National Climate Change Response Strategy
NDVI	Normalized-Difference-Vegetation-Index
SDG	Sustainable Development Goals
SPSS	Statistical Package of Social Science
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WMO	World Metrological Organization
WWF	World Wildlife Fund

ABSTRACT

Fragile ecosystems in the Arid and Semi-Arid Lands of Kenya are highly vulnerable to climate variability, yet they hold most of the nation's livestock and wildlife. The pastoral Maasai community living in Amboseli Ecosystem in Kajiado County provides a good case study of semi-arid regions in Kenya experiencing serious challenges stemming from climate variability and its adverse effects on their livelihood. The aim of this study was to determine the relationship between climate variability and livelihood vulnerability among the Maasai pastoralists in the Amboseli Ecosystem. The specific objectives were to: assess trends in key climate variability indicators during the period 1988-2018, evaluate the effects of climate variability on pasture and water availability, determine the effect of climate variability on livelihoods, and to determine the adaptation strategies adopted by different households to minimize vulnerability to the effects of climate variability and change. The study used explanatory research design which focused on descriptive and correlational approaches. This study targeted a population of 47, 058 residents from which a sample of 384 household heads was selected. Cluster and convenient sampling were used for quantitative and qualitative data respectively. A questionnaire with open and closed ended questions and with Likert scale format was used to collect quantitative data while interview schedules were used for qualitative data. In addition, secondary data was collected from different sources but primarily from Kenya Meteorological Department repositories. Descriptive statistics and content analysis were used to analyze qualitative data while quantitative data was analyzed using inferential statistics. One-way ANOVA, regression beta parameters and t-statistic were used to assess significance of correlation between adaptation variables. Normalized-Difference-Vegetation-Index technique was used to make content analysis of pasture and water distribution. Mann Kendall method in XLSTAT program was employed to test for significance of trend in temperature and rainfall data over three decades. Vulnerability assessments were conducted at household level. Climate variability analysis revealed an increasing temperature trend with a p-value of 0.36 and a decreasing trend in precipitation with a p-value of 0.02. It also showed that pasture and water availability increased with increasing rainfall trend and vice versa. Vegetation greenness and water availability reduced as temperature increased resulting due to enhanced evapotranspiration and water evaporation respectively. These changes affected both livestock and crop production. Vulnerability of livelihoods was found to have a direct relationship with availability of pasture and water. Milk production, animal health and reproduction were the main climate-related factors influencing household vulnerability. The common adaptation strategies adopted were herd reduction, mixed livestock, mixed farming, water harvesting and small businesses. These strategies reduced vulnerability of households but are not advancing fast enough to offset the adverse effects of climate variability. It is therefore imperative to build capacity of households and help them to diversify their sources of livelihood and adapt to changing climate. Going forwards, state could empower households and build resilience of the community against unpredictable climatic changes. Further research is needed to evaluate the effectiveness of the existing adaptation strategies and determine priority areas of capacity building at household, community and county government levels. Harmonious co-existence between residents and wildlife is critical since wildlife sustains revenue streams from ecological and cultural tourism, both of which can significantly enhance community resilience against inevitable climate variability and change.

CHAPTER ONE: INTRODUCTION

1.1 Background Information

Climate variability pertains to deviations in the fundamental components of climate, particularly temperature and rainfall, from their long-term averages. This variability is primarily driven by natural mechanisms, including periodic alterations in the circulation patterns of air and ocean currents, among other contributing factors. These fluctuations in climate pose significant risks to natural ecosystems and various economic sectors that are highly sensitive to climate conditions, such as agriculture, livestock, public health, and water resources. Indeed, climate variability has had detrimental impacts on all segments of economic production, with rural areas around the world being particularly affected.

The fluctuation in climate patterns in Africa has had a harmful effect on the ability of people living in rural areas to make a living and presents a significant danger to the general health for rural populations according to the findings of Innocent (2017). Africans states to the south are expected to experience sensitivity of climate change as regions of the world, mainly due to their substantial reliance on rain water for agribusiness and pastoralism. Moreover, the people residing in this area possess restricted ability to adjust to changes in weather patterns (Omotoso et al., 2023). Africa's rainfall patterns are greatly impacted by factors such as El Nino-Southern Oscillation (ENSO), which can occur during a single season or extend over numerous years. These phenomena can result in predictable weather events and subsequently lead to food shortages (Huang et al., 2020). Africa's climate is marked by a wide array of variations and diversity (Lyon & Vigvad, 2017; Van der & Warner, 2019). There is compelling evidence to suggest that Africa's climatic and environmental conditions

are currently undergoing substantial and ongoing transformations. Pastoralism is the dominant land use worldwide (Reid et al., 2014) and is commonly employed in regions characterised by extreme and unpredictable climate conditions. Cotrell et al. (2015) observed a rise in livestock losses in the Arid and Semi-Arid Lands (ASALs) worldwide, which has been related to the detrimental impacts of climate variability. The insufficiency of rainfall, rising temperatures, and the growing occurrence of droughts in Africa have diminished the availability of irrigation for agricultural and pastoral activities (;Omotoso et al., 2023 , Kwame et al., 2022). Conventional herding is economically viable (Bacher et al., 2023), but it relies heavily on the stability of water supplies and pasture. Climate change and variability have a substantial impact on the lives of pastoralists in the Arid and Semi-Arid Lands (ASAL) regions of Africa, particularly in terms of the availability of food and water (WHO, 2023) Research undertaken throughout several regions of the African continent has consistently demonstrated that crop failure is a recurring occurrence, leading to widespread hunger, malnutrition, human migration, and ethnic strife. Moyo et al. (2023) and Ombogo (2013) observed that alterations in precipitation patterns, both in terms of quantity and distribution, will result in modifications in land utilization, heightened deforestation, ecosystem degradation, and finally, the conversion of Africa into a desert. In the absence of sustainable measures implemented by state governments and communities to halt or reduce this trend, the situation will exacerbate poverty and food insecurity, thereby resulting in climate-induced internal conflicts and human fight from the continent.

Kenya, positioned in the Horn of Africa, is situated in a vulnerable area that is prone to climate oscillations, leading to fluctuations in rainfall patterns and extended periods

of drought. Evangelou, (2019) said that the country is vulnerable to drought, periodic floods, and other disasters because approximately 80% of its territory is categorized as Arid or Semi-arid land (ASALs). On the other hand, Kenya has put in place National Climate Change Response Strategy (2010) to cushion the country against the effects of Climate variability and change by increasing public awareness giving various recommendations to adapt and mitigate climate change, as well as establishing institutional frameworks on the same. KARI's research in 2020 uncovered significant climate-related challenges that dryland ecosystems encounter, directly affecting the well-being of local residents and the natural resources they rely on. On the other hand, the Kenya National Adaptation Plan (2015-2030) has enhanced resilience in the attainment of Vision 2030 although a lot needs to be done on adaptation capacity at the household level

According to the 2014 assessment from the IPCC, the pastoral regions in the Horn of Africa face the greatest danger of drought and negative impacts on their way of life owing to changes in rainfall patterns and increasing temperatures. Moreover, Morton's observations in 2010 emphasizes that the ability of East African pastoralists to support themselves is deteriorating at a faster rate compared to other rural livelihoods.

Fankhauser, 2017 study emphasizes the advent of new climate conditions in Eastern Africa and stresses the need for the livestock producing industry to develop adaption methods to reduce negative effects. Apollo et al., 2021 research reveals that climate change is impacting conventional resource utilization and livestock management methods, which in turn affects gender roles. These exposes both men and women to unique difficulties and possibilities. The research conducted by Western et al., 2020

highlights that the cattle numbers in Kenya and other parts of Africa have considerably declined due to the detrimental effects of dehydration and degradation. Evidently, numerous pastoralist groups in Kenya are progressively transitioning from ancient pastoral farming to agro-pastoralism and alternative livelihood practices that need a settled lifestyle rather than a nomadic one. Kenya's climate change act of 2016 (No. 11 of 2016) intends to promote low carbon development by encouraging climate smart agricultural practices and promoting agricultural transformation as stipulated in the Agricultural sector transformation strategy (2019-2029). Nevertheless, the examination of this climate-induced transformation in Kenya has been insufficient, and the manner in which communities are adjusting to the detrimental consequences of climate fluctuations at the household level remains uncertain. The objective of this investigation is to analyze the impact of climate unpredictability on the occupations and daily activities of the Maasai people who live within semi-arid territory of southern Kenya.

1.2 Statement of the Problem

The Maasai pastoralists residing within Kajiado's environment of Amboseli, Kenya, are facing a critical challenge stemming from climate variability, which has severely impacted their livelihoods and rendered them increasingly vulnerable. This unique ecosystem, known for its delicate balance between human activities and nature, is undergoing significant shifts due to erratic climatic patterns and resulting changes in land use. These changes are adversely impacting on the traditional practices and resilience of the Maasai pastoralists (Ombogo, 2013). This study seeks to understand how the pastoralists in Southern Kajiado County, specifically in the Amboseli Ecosystem, are coping with stresses of climate variability. The study will establish

the extent of climate variability by analyzing precipitation and temperature data for three decades (1988-2018). The convergence of these ecological changes and socio-economic factors presents a pressing issue that demands a thorough comprehension of the intricate relationship between climatic variability and livelihood vulnerability of these pastoralists. Urgent attention is required to investigate the specific manifestations of climate variability; identify the vulnerabilities it exposes to the Maasai community as identified by Kajiado Participatory Risk Assessment (2023-2027). Devise targeted strategies for sustainable adaptation and mitigation that can preserve their centuries-old way of life while enhancing their ability to withstand the challenges posed by an increasingly unpredictable climate.

1.3 Research Questions

- 1) How are the trends in temperature and precipitation in Amboseli ecosystem during the period between 1988 and 2018?
- 2) How has climate variability changed the presence of grazing land and irrigation resources in Amboseli Ecosystem during the period between 1988 and 2018?
- 3) How has climate variability affected household income and food availability in Amboseli ecosystem?
- 4) What adaptation strategies have been adopted by different households to minimize vulnerability to the negative impacts of climatic fluctuation?

1.4 Objectives of the Study

The primary aim of this research was to establish how variations in climate are leading to vulnerability in the well-being of Maasai pastoralists in Kajiado County. This has additionally been subdivided into particular aims:

1. To assess temperature and precipitation trends in Amboseli ecosystem during the period between 1988 and 2018.
2. To evaluate the effects of climate variability on pasture and water availability in Amboseli Ecosystem between 1988 and 2018.
3. To determine the effects of climatic variability on household vulnerability in Amboseli Ecosystem during the period between 1988 and 2018.
4. To determine the adaptation strategies adopted by different households to minimize vulnerability to the adverse impacts of climatic variability and change.

1.5 Research Hypotheses

Ho (1) There is no change in the trends of temperature and rainfall during the period between 1988 and 2018 in Amboseli Ecosystem of Kajiado County.

Ho (2) there is no significant effect of climate variability on pasture and water resources during the period between 1988 and 2018 in Amboseli Ecosystem of Kajiado County.

Ho (3) there is no significant effect related to the variability in climate on household income and food availability in Amboseli Ecosystem of Kajiado County.

Ho (4) the adaptation strategies adopted by the community are not reducing household vulnerability to climate variability and change.

1.6 Justification

Traditional pastoralism is dependent on rainfall for pasture regeneration and water supply for crop production and consumption by people and livestock. Any persistent changes in the quantity and pattern of rainfall could adversely impact utilization of

grazing land as water potentially accessible from the streams, water pans and shallow wells.

There is growing demand for water and pasture in all the pastoral areas in Kenya and Climate variability has aggravated the situation even further as identified by the National climate change response strategy (2010).

Climate variability together with socio-economic changes of external origin have significantly shaped the traditional way of life for the Maasai nomads. Yet, there is a lack of extensive records on the impact of climate variations and the vulnerability of Maasai nomads' livelihoods in Kenya. According to IPCC (2014), livelihood vulnerability to climate variability and change is a function of how long a community has been exposed to adverse effects, the sensitivity of its production system, and its capacity to adapt. According to Ngoula et al., (2017), exposure refers to environmental changes that can be explained by seasonal variations associated with precipitation and temperature. In addition, the study will contribute to the academic knowledge on climate variability and how it causes vulnerability at the household level.

The livelihoods of Maasai communities of southern Kenya are vulnerable to climate variability. This study seeks to find out how climatic conditions have been changing and how the changes have influenced water and pasture availability. The study also sought to document the existing adaptation strategies and evaluate the extent which they have diminished the vulnerability of households to fluctuations in climate in the Amboseli Ecosystem of southern Kajiado County. The baseline year was taken as

1988 and the closing year was 2018. This period was selected so as to access a complete data sets for water and climate.

The results of this research would provide a valuable contribution to the attainment of United Nations Sustainable Development Goal 13 (Climate Action), Sustainable Development Goal 1 (Ending all kinds of poverty), and Sustainable Development Goal 2 (Zero Hunger). The study's results would also contribute to the realization of Kenya's Economic Blue Print (Vision 2030) and National Environment Change Action Plan. Kajiado County's Amboseli, Ecosystem is situated in the semi-arid region of southern Kenya. The findings of this study would offer guidance to natural resource managers, agricultural and livestock managers, and give crucial contextual information for the benefit of future researchers working within dry regions of Kenya.

1.7 Scope and Limitations

The researchers visited six separate group ranches inside the Amboseli environment situated in Kajiado County. The group ranches encompassed in this list are Olgulului-Ololarashi, Eselenkei, Imbrikani, Kimana, Kuku, and Rombo. This investigation solely focusing towards the repercussions related to weather variations on individuals' capability to maintain their means of subsistence. The Amboseli environment may exhibit distinct characteristics that differentiate it from other pastoral areas in Kenya. Without more investigation, it is premature to generalize research findings from the study of nomadic groups throughout the nation. In addition, the research only employed questionnaires, focus groups, and interviews. Given the researcher's inability to ascertain the veracity of the respondents, it is logical to presume that the outcomes and responses obtained from these instruments are reliable depictions. To ensure convenience, we have used the previously indicated approaches for collecting

information. Given NDVI was used in analyzing vegetation cover, it is limited in a number of ways. For example, the accuracy of NDVI method is limited in certain plant phenological phases, variable plant saturation levels and sensitivity to soil effects in areas with very low vegetation cover. Further, the method generates ordinal scale data, which are not suitable to inferential statistics without supportive ground vegetation sampling. However, the method is reliable for landscape scale vegetation surveys.

1.8 Conceptual Framework

The intellectual framework depicted in Figure 1.1 demonstrates how climate variability in terms of precipitation and temperature affects Pasture and water availability. It also shows how adaptation strategies affects household vulnerability in terms of income, food security, malnutrition and frequency of resource-based conflicts. Land and the natural resources are intervening variables on adaptation strategies since resource use decisions are largely made at community level. These strategies are influenced either positively or negatively by several external factors (control or intervening variables), such as prevailing climatic conditions, national and county government policies or interventions to which a household has no control.

INDEPENDENT VARIABLES

DEPENDENT VARIABLES

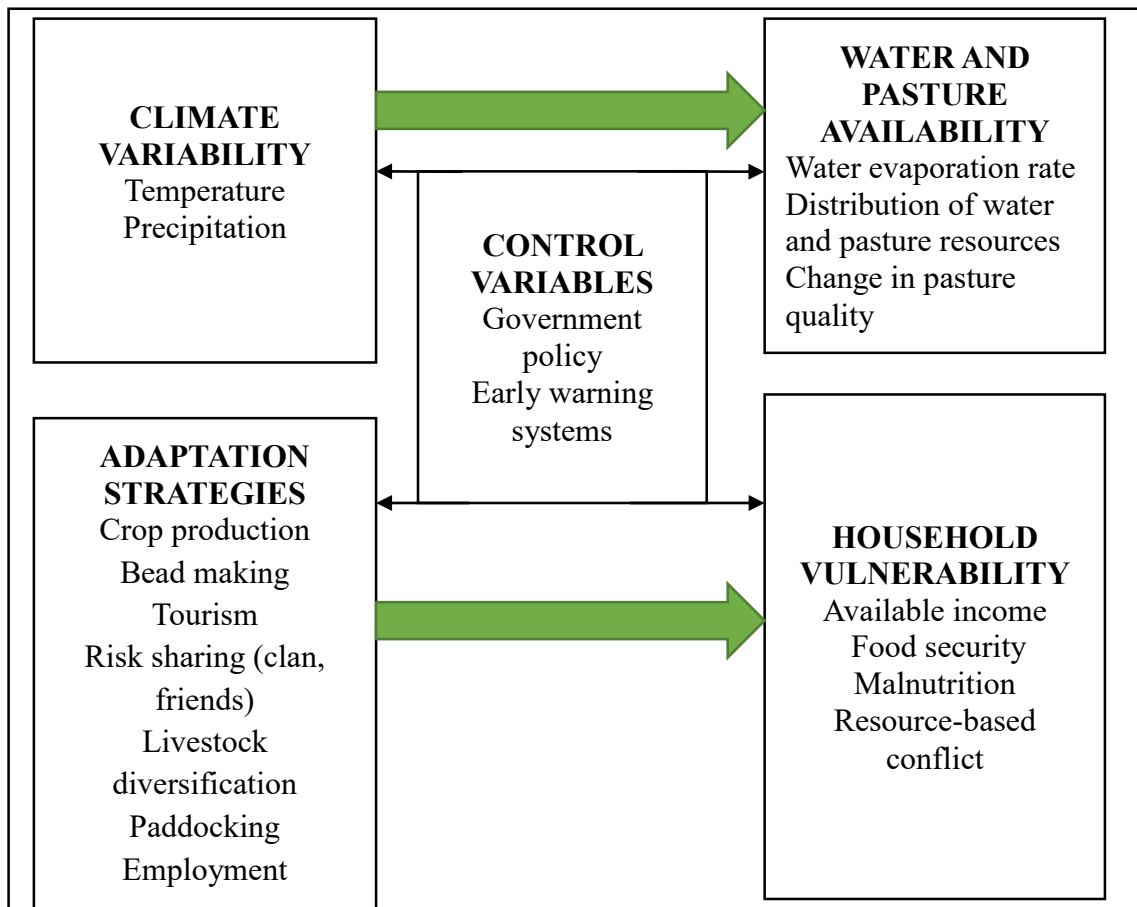


Figure 1.1. Relationship between climate variability and livelihood vulnerability

1.9 Operationalization of terms

Climate variability: The variation in the climatic factors of a geographical area from its prolonged average, exceeding isolated weather occurrences (Ghil & Lucarini, 2020). It was measured in terms of seasonal rainfall and temperature variations of the study area

Pastoralism: A way of life based on rearing livestock exclusively on extensive areas of land with natural pasture. (AEMP 2008-2018). This was measured in terms of the number of livestock and the type of livestock owned.

Livelihood: The method of acquiring the essentials for survival or sustaining one's being (AEMP, 2008-2018). Pastoralism was the main source of livelihood under investigation.

Climate change: The increasing shifts in the metrics of weather (encompassing alterations in rainfall, temperature, and wind trends) throughout a duration of more than thirty-five years (IPCC 2014).

Adaptation strategy: A plan or mechanism (including framework, tools and methods) of managing climate related risks and impacts (Balis et al., 2022). It was measured in terms of crop growing, employment, small business enterprise, Tourism/beading, risk sharing and livestock diversification

Livelihood vulnerability: The susceptibility of a livelihood system to negative impacts of global warming (including fluctuations in weather patterns and occurrence of severe climatic events), and its inadequate capability to adjust to these changes. Vulnerability encompasses both biological and social factors but in this study, it

focused on ways and means of producing essential goods and products needed by households for survival.

Exposure: the state of having no protection from something harmful. (Oxford online dictionary) Exposure in this study was investigated in terms of repercussions that weakened both community's and household's resistance to climate hazards, shocks, and stresses.

Adaptive Capacity: the ability of a system, community, or region to adjust to change, including climate change, and to reduce the likelihood of harmful outcomes. (UNFCCC) Rural households often possess less resources and exhibit a weaker capacity for adaptability. Social vulnerabilities to climate variability and change might be indicated by factors such as growing economic disparity, weakening support from cultural networks, rising isolation or urbanization, and slower economic progress. (Kaguny, 2014). In this study, adaptive capacity was investigated in terms of the household's ability to cope with climate induced stresses by having more than one source of livelihood.

Sensitivity: How much people are affected by climate variability and how vulnerable they are to its impacts (WHO, 2023) this study looked household's vulnerability to the unpredictable changes in rainfall and temperature patterns for a period of thirty years in Amboseli Ecosystem.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Under this chapter, a comprehensive overview for prior research pertaining this current subject has been given highlighting any existing deficiencies or areas that have not been adequately addressed. The text is organized into three primary subsections, each examining topics that are relevant to the unique goals of the study. The initial portion focuses on climatic variability patterns, as shown by alterations in temperature and precipitation.

2.2 Climate Variability Trends

2.2.1 Temperature Trends

There is an increasingly widespread agreement on variability of climate which could be a serious issue on a global scale because of the damage it may do to ecosystems, food supplies, human health, economies, ecosystems, and built environments. On top of that, it's a major threat to sustainable development's future success (IPCC, 2007). Kenya is one of Africa's most susceptible nations to the effects of global warming. This is primarily because rain is essential to nearly all of Kenya's agricultural output (UNEP, ILRI 2021). Because of the importance of agriculture to Kenya's economy, the country is particularly susceptible to the destructive consequences of rising temperatures, droughts, and floods. The environmental conditions greatly diminish agricultural output. Several studies (Byers et al., 2018; GoK, 2016) show that Kenya is already feeling the effects of climate change, and these effects are having serious and worrying consequences. Pastoralism, a major source of food security and rural employment, has suffered from climate unpredictability and change. The scenario is

also likely to worsen in the future. More than 60% of the population in certain dry and semi-arid counties in Kenya is poor. More than half of pastoralists' cattle died during droughts in the last decade (Byers et al., 2018) Monitoring local weather patterns is essential for doing research and preparing for challenging conditions. Keeping an eye on regional trends provides scientists with information for developing accurate climate models (Ceccato et al., 2014). Weather and temperature data are useful, but so is information on the state of the regional food supply. Remember that understanding the current climate, agricultural practices, and market conditions in addition to historical climate data is essential. Having this information at your disposal allows you to make choices based on species' adaptability to different climates and the expected severity of annual natural disasters (Johansson et al., 2015). Monitoring disease outbreaks is especially important because most illnesses emerge in response to alterations in the weather and climate. If we want to make the most of what we know about climate variability, it is also crucial that politicians and scientists communicate effectively. Recent and historical climate trends and measurements provide output monitoring on a local and global scale.

According to Cornwall (2016) revealed that global temperatures have experienced a rapid increase in the past century. As per the IPCC's Third Assessment Report (TAR), the global mean surface temperature is projected to increase by $0.6 \pm 0.2^{\circ}\text{C}$. According to the IPCC, temperatures are projected to increase by a range of 1.4 to 5.8 degrees by the year 2100 as a result of this pattern. Scientists anticipate that a doubling of carbon dioxide (CO₂) levels in the lower atmosphere over the next 50 years might result in temperatures ranging between 1-3C° in the world's arid regions. Based on

GCM forecasts (Duguma et al., (2017) it is anticipated that atmospheric CO2 levels might reach 700 parts per million by the year 2100.

Predictions for the rest of this century in Africa are for consistently high temperatures during every season, in line with global temperature trends (Wright et al., 2021). Warming was most in the decades after the 1970s and from the 1910s to the 1930s. All parts of Africa and the rest of the world will experience the same warming at the same times (Fankhauser,, 2017). Sub-Saharan Africa is particularly vulnerable to the effects of climate change because of its high average temperatures and its poor, highly variable rainfall. Agricultural exports drive regional economies, but residents' access to and understanding of modern technology are constraints (Etwire et al., 2019) Kenya's coastal and mountainous regions have vastly different average temperatures throughout the year. Temperatures can reach 30 degrees Celsius in the shaded interior lowlands (GOK, 2016), but can drop to 16 to 25 degrees Celsius in the sunnier highlands. The average high in the Lake Magadi basin is 34 degrees Celsius, while the average low on the slopes of Mount Kilimanjaro and the Ngong Hills is 10 degrees Celsius (GOK, 2016). The Intergovernmental Panel on Climate Change (IPCC) concluded in its fourth assessment report in 2007 that global warming is real and unavoidable. The unique biodiversity of the Amboseli Ecosystem and the way of life of the local agro-pastoralists are both threatened by rising temperatures.

Records show that as air temperatures rise, icy precipitation melts across large areas atop Mount Kilimanjaro, surface water resources decrease due to intense evaporation, pasture resources decrease, and agricultural and livestock production decrease significantly due to water stress.

2.2.2 Rainfall Trends

According to Dieppois et al.,(2015) , the ENSO models predict modest alterations in African rainfall, particularly in contrast to the historical variations in rainfall. Sub-Saharan Africa often experiences below-average rainfall, while certain areas have seen above-average precipitation. Evidence from multiple research points to a significant climate shift in the Sub-Sahara, one that has reduced rainfall over the long period across West Africa and the Sahel as a whole, as indicated by research from Giorgi et al., (2019) along with Nicholson et al., 2018, the rainfall pattern is mostly triggered by ITCZ. The distribution pattern regarding the rainfall in this area is subject to local variations attributed to the effects of topography and the presence of significant inland water bodies, as highlighted by Abdi et al.,(2023)

Consistent with the research conducted by Davis et al., (2017) the Horn of Africa experiences periods of unusually intense precipitation and floods in places with low elevation, typically happening once every ten years. Projections indicate that the occurrence of such incidents will increase during both the brief and extended periods of rainfall. East Africa, as a whole, experiences a stable rainfall pattern, with some signs of long-term increases in precipitation levels, due to the increased likelihood of higher average annual rainfall. In addition, the 2007 IPCC report states that East Africa is seeing a strengthening dipole rainfall pattern over a period of 10 years, with increased rainy seasons to the north regions as well as decreased precipitation to the regions to the south.

The varied geography of Kenya, together with its large interior water bodies such as Lake Victoria, significantly influence the country's very variable climate. According

to the IPCC, the amount of rainfall in different locations ranges from 200 mm in the driest areas to 1,200 mm to 2,500 mm in the wetter parts along the Lake Victoria shoreline and in the central highlands east of the Rift Valley. The various geographical characteristics and height variations of Mount Kilimanjaro, Mount Elgon, Mount Kenya, and the Mau Hills Complex contribute to the development of regional climates as revealed by various literatures.

Koech et al. (2020) observed that climate forecast for Kenya's ASAL would include extended and more frequent drought spells, alternating with intense yet shorter and unpredictable rainfall episodes. This statement may be considered a broad conclusion. Therefore, studying the Amboseli ecosystem provided an opportunity to gain a deeper understanding of its dynamics and difficulties, and how they could be relevant in other contexts. In 2009, Kajiado saw a three-week delay in and below-average prolonged rainfalls, along with inadequate temporal and geographical dispersion, as reported by the Duguma et al., (2017). The Mashuru and Namanga groups were particularly prominent. This study addressed a crucial knowledge gap in our comprehension of the Amboseli environment, which is primarily dependent on cattle for sustenance.

Kajiado has bimodal rainy seasons, characterised by short bursts of rain in the autumn (October-December) and prolonged periods of rain (March-May). The seasonal rainfall rhythm of the Kajiado sub counties/ wards progressively transitions from east to west, as observed by Evangeluo, (2019) In their study, Bekure et al. (1991) discovered that the long rains occur more frequently in the eastern region of Kajiado compared to the western region. Conversely, the short rains are more prevalent in the western region. The highlands near Loitokitok see significantly higher annual

precipitation with an average of 1,250 mm, whereas the lowlands around Lake Magadi and Amboseli receive a much lower average of approximately 500 mm (GOK, 2016; Ombogo, 2014).

The Uaso Nyiro River, the Kiboko River, and other springs in the southern part of the Amboseli ecozone serve as the main sources of surface water, draining a significant amount of the Central Hills and the northern area of the Amboseli ecozone. The vegetation of Mashuru Division varies from open grasslands to densely populated shrublands, with certain areas of the region's main hills covered in forests (Mganga et al., (2018)

The study addressed a previously unidentified lack of information on changes in temperature and precipitation during the preceding ten years. This research has a broad scope, encompassing the entirety of Kenya, and therefore does not specifically examine the unique characteristics of the Amboseli environment in Kajiado.

2.3 Influence of Climate Variability on Water and Pasture

2.3.1 Influence of Climate Variability on Water

Freshwater sources are seriously under risk as a result of in the context of climate change, as per the research by Huggins et al (2022), 29% of the African population live in water shortage areas posing a challenge to availability and accessibility of this important resource. 69% however live in water abundance. Due to population expansion, socioeconomic and technical advancements, demand for water is increasing globally day by day. Climate change on the other hand is increasing strain on freshwater supplies Oertli, B. (2018). Water plays a very significant role in social and economic growth. Due to its scarcity, economic growth slows down, yet the

World over, water is viewed as a resource that is replenish able within the constraints of a fixed regional climate Dickinson et al., (2017)

Climate change-induced water shortages, characterized by their unpredictability, long duration, and extensive geographic coverage, can have a detrimental and demoralizing effect on the local economy and perhaps even the national economy Zulfiqaret al., (2021) Increased flood strength and frequency, as well as more intense precipitation events, will lead to higher surface runoff and erosion. This, in turn, will result in an increased nutrient load to surface water Salmaso et al., (2018). Higher temperatures accelerate the release of phosphorus from bottom sediments (Verbeek et al., 2018). Urban and peri-urban areas will have drainage and sewage disposal problems due to the heightened intensity of rainfall. The collapse of low capacity or damaged systems is anticipated to lead to a rise in pollution leve (Noël et al., 2022). Anas et al., study (2021) found a clear relationship between precipitation, runoff, or discharge and the presence of waterborne pathogens or faecal indicator organisms in surface water.

Van Loon et al. (2022) found that floods and droughts increase the likelihood of elevated levels of bacteria, pollutants, and radioactive hazards in drinking water. Furthermore, floods and droughts would exacerbate many forms of water contamination, such as sediments, nutrients, organic carbon, infections, and pesticides, so posing a significant threat to entire neighborhoods and towns in terms of the spread of human waste and related health risks (Howard et al., 2020). The occurrence of floods and landslides caused by rainfall can lead to a depreciation of the existing water and sewage infrastructure, especially if they are located outside of residential properties.

The anticipated increase in rainfall intensity and irregularity is expected to result in higher inter-annual variability in river flows, leading to a more pronounced 'flashiness' and seasonality of rivers. Based on a study conducted by Moyo et al. (2023), it is predicted that there would be an increase in the frequency of flood occurrences. Additionally, a larger proportion of surface water will be lost during peak flows, resulting in a decrease in the amount of readily accessible water. The capacity of the atmosphere to retain water increases with higher temperatures, resulting in an anticipated increase in evaporative demand in virtually all regions (Stocker, 2014). Climate change will profoundly impact water availability across all industries. Drought-induced dry spells result in decreased water levels in glaciers and snow cover, as well as increased occurrences of floods (Klein et al., 2014). Increasing water shortage would intensify competition among many businesses and sectors, such as agriculture, residential, commercial, and industrial. Pumping groundwater at a rate above its recharge rate leads to a depletion of groundwater in the aquifers (Howard et al., 2020). As per the Department for International Development (DFID), drought poses significant hazards such as the possible depletion of water wells and dams, resulting in water scarcity in both rural and urban regions.

Muriithi (2021) predict that by the end of the millennium, the average annual temperature in Kenya will have increased by 3 to 50 C due to global warming. When temperatures rise, water evaporates and dries out faster. Due to the combination of rising temperatures and falling precipitation, pastoral rangelands are becoming increasingly drier, threatening the availability of vital resources such as water, pasture, and wild edible fruits on which pastoralists depend (Van Weezel, 2019).

A mass loss of livestock could have devastating effects on pastoralists' safety and way of life (Sazib et al., 2020). Pastoralists' livestock serve as the economic, social, and political backbone of their communities. Pastoralists lose their privilege and status in society when they lose their animals (Varis et al., 2017). Pastoralists, who typically live in dry or semiarid areas, are especially susceptible to the economic effects of climate change on agriculture and animals. As a result of global warming, these areas are experiencing more frequent droughts. Pastoralism has persisted quite well despite all of these obstacles.

The impact of climate change on African water systems manifests through alterations in temperature, precipitation patterns, and the hydrological cycle (Kew et al., 2021). A research conducted by Brousse et al., (2020) found that climate change in Uganda is responsible for 98% of the occurrence of water shortage. Similarly, the IPCC acknowledges Kenya as one of the nation's facing water scarcity. Furthermore, other scholarly works, such as those Land R D (2016), Kihwele et al., (2021), and Gemedo et al., (2023) provide evidence that water shortage is a significant driver of conflicts in both Kenya and Tanzania. However, the research fail to demonstrate the causal relationship between these conflicts and the vulnerability of pastoral livelihoods. The availability of pasture and water is crucial for pastoralists as it directly impacts their way of life. Therefore, it is necessary to establish sustainable adaptation solutions to address this issue, which is the focus of this study. Butler et al., (2020) has provided evidence for the notion that locations inhabited by pastoralists experience low and unpredictable levels of rainfall, together involves elevated temperatures as well as challenging landscapes.

Climate variability and change have demonstrated their effects on various aspects of water resources, as noted by Zhao et al., (2022) The shifts in water distribution are thought to affect both subterranean and surface water supplies, thereby influencing water availability, usage, accessibility, affordability, and pricing, as emphasized by Brousse et al., (2020)

2.3.2 Influence of Climate Variability on Pasture

The regional, local, and household levels of economic activity in Africa are all feeling the effects of climate change. Rummukainen, M. (2016).found that this was having a major effect on the agricultural and water resources sectors. According to IPCC (2007), the African continent had a more marked warming trend throughout the 1960s. These tendencies, however pervasive they may appear to be, are temporary. According to the Intergovernmental Panel on Climate Change (IPCC, 2007), tropical African forests have warmed at a decadal pace of 0.29°C, whereas South Africa has warmed at a rate of 0.1 to 0.3°C. The Royal Society has done extensive model simulations that suggest a 20% reduction in the duration of the agricultural growing season by the year 2090 if the global temperatures increases beyond 4 degrees celcius. This reduction is likely due to higher precipitation and warmth in the region. Rising temperatures combined with climatic unpredictability could severely reduce agricultural production, costing the agriculture sector dearly.

In both South Africa and Ethiopia, the smallest temperatures have risen a little more quickly than maximum as well as average temperature (Conway, et al., 2019). Between 1961 and 2000, the frequency of warm spells increased while the frequency of really cold days decreased in Southern and West African regions (Dunn et al., 2020). Yusuf et al. (2017) discovered that weather observatories along the shoreline

or near large lakes throughout eastern Africa had seen warmer-than-average trends. Mount Kilimanjaro's natural ecosystems are also undergoing dramatic shifts, which scientists attribute to climate change. Solar radiation and small-scale processes are two examples of the feedbacks and interactions that contribute to these shifts (Lemke et al., 2007). According to Moyo et al. (2023), Mount Kilimanjaro's ice caps shrank by almost 80% throughout the course of the twentieth century.

There will be a rise in temperature across the board for each of Kenya's four seasons based on availability of rainfall or lack of it thereof (S-O-N, D-J-F, J-J-A wet, dry seasons) this century, according to projections. Under a medium emission scenario, Moyo et al. (2023) predict a 3 to 4 degree Celsius rise in yearly average surface air temperatures by the year 2099. This forecasts a temperature increase that is 1.5 times faster than the average for the entire planet. Annual precipitation is predicted to increase by around 7% as a result of this shift (Moyo et al., 2023), while the precise amount will vary depending on location and time period. Variability in rainfall, which includes aspects like when, where, and how much precipitation occurs, has a major impact on a population's ability to adapt. Rainfall intensification alone is not responsible for this effect (Maishanu et al., 2019). Through their article they stated that due to rising temperatures and greater unpredictability in rainfall, the area may anticipate more severe and frequent extreme weather occurrences. This would increase the risk in many places of East Africa by causing longer droughts and more intense storms.

The predicted weather in Kenya is very similar to these regional patterns. The IPCC (2007) predicts that between the years 2060 and 2090, the average annual temperature in the nation would rise by 1–2.8 degrees Celsius, and by 1.3–4.5 degrees Celsius,

respectively. From October through December, you may expect the greatest percentage increase in yearly precipitation, with the largest individual rise coming in January and February. Regional heterogeneity means that the areas around Lake Victoria and the central highlands east of the Rift Valley in Kenya will likely have the greatest increases in precipitation. The IPCC (2007) predicts that an overall decrease in rainfall will occur in the eastern and northern ASALs due to climate variability. Moreover, when temperatures rise, evapo-transpiration rates will rise along with them, reducing the impact that rainfall has on soil water availability for crop cultivation. There is likely to be regional and geographical variation in the effects of climate change on farming. This calls for an in-depth knowledge of the causes and effects, as well as the planned creation and distribution of appropriate solutions (Kumar et al., 2020).

Extreme weather events and climate change both contribute to water scarcity and stress. The Intergovernmental Panel on Climate Change (IPCC) warns that changes to the hydrological cycle, temperature equilibrium, and precipitation patterns would have severe consequences for Africa's water system, including Kenya's. Unsustainable usage and uneven geographic accessibility are two hallmarks of water resources including rivers, lakes, and rains (IPCC, 2008). That's why scientists believe climate change is to blame for our current water crisis Brousse et al., (2020) analyzed the Chahi sub-catchment in Uganda's Kisoro area to assess water use and management. The results showed that climate change was responsible for nearly all of the water shortage. Scientists have established a link between water shortage and violence in Kenya and Tanzania. When social systems are under stress and other resources are limited, this association becomes more pronounced. Moyo et al., 2023

as well as Howard et al., (2020) have all offered evidence for this connection. However, Linke et al. (2018) state that water shortage does not cause or contribute to wars.

The decline of grasslands is a global threat to human health. Kajiado is home to a wide variety of plant life, with grasslands, woody shrublands, and even some forests in the Mashuru region (Mganga et al., 2018). Pastoralists have had to come up with adaptation techniques because of the threat that rising temperatures and fluctuating rainfall pose to the availability and accessibility of pastures (Howard et al 2020). According to Ombogo (2013), there is more grazing in Amboseli during the brief wet season (November–January) than in the dry season (April–May). After this, pastures become increasingly scarce between June and August. The purpose of this research is to fill a knowledge gap regarding the ease of access to and availability of pasture during the wet season. As predicted, high temperatures have an effect of increasing evaporation and decreasing transpiration. Convention on Biological Diversity (2010) notes that many pastoral systems have long roots in traditional management and practises. Soil fertility and seasonal precipitation greatly affect the quality of pasture, and in turn, the quality of beef and other cow products. Changes in weather between seasons and within a season can have an effect on the quantity and quality of the fodder available.

2.4 Livelihood Vulnerability of Pastoral Maasai Households

As a result weather variations, majority of people in the ASALs have had to modify living habitats in various ways (Matsaba et al., 2021). Climate change is having an impact on both Kenya and Tanzania, putting at risk the livelihoods of many people, especially those who make their living in the agricultural and livestock sectors. Due

to economic losses caused by climate instability, pastoralists are now reliant on food and water aid. Small businesses and agricultural output are examples of adaptive strategies, however the study does not prove that they reduce family vulnerability. Jandreau & Berkes (2016) argue that climate change and variability are harmful to human health. Several vector-borne and water-borne diseases, according to Warren et al., (2021), are a direct outcome of global warming. To paraphrase Simen-Kapeu et al., (2021): "poor communities with few resources are likely to be more vulnerable to climate change." By analysing how climate change affects household income and food availability, particularly during dry seasons when pastoralists must move their animals in search of pasture and water, this study sheds light on the connection between household vulnerability and climatic variability. Gumel (2022) claims that a household's vulnerability varies based on a variety of characteristics, such as its income, education, welfare, skill level, access to affordable credit, awareness of early warning systems, availability of labour, political will, and political competence. The biophysical technique, as described by Davis & Vincent (2017) and elsewhere, measures an individual's vulnerability to shocks and pressures resulting from climate variability. Fenta et al. (2019) state that the primary focus of the impact assessment method is on the observable consequences of climate change on a variety of environmental parameters.

Over 70% of livestock items on the Kenyan domestic market would originate from pastoralists by 2020, according to a study by Moyo et al., 2023. This proves without a reasonable doubt that pastoralism has a large impact on a country's gross domestic product and economy. The majority of Kenya's pastoralists make their homes in ASALs, which are extremely susceptible to weather changes. The Rift Valley counties

of Kajiado, Narok, and Transmara, as well as parts of West Pokot and Laikipia, are good examples of such rangelands. Climate-related stresses, such as the drought of 2008-2009, periodically take a toll on these areas. According to Ombogo (2013), NDVI was used to assess the county's response strategy in Kajiado. Satellite imagery was used to evaluate the state of rangeland collapse. This research, however, did not show how pastoralists may lessen their vulnerability by employing coping strategies, nor did it examine the impact of household parameters like milk yield, market prices, family income, and herd size on vulnerability in the face of drought. To address this, the current research activity provides evidence of the lived experiences linked to each vulnerability indicator and the related adaptation strategy. The inability to adapt to some droughts has led pastoralists to expect governments and relief agencies to rush in with massive quantities of aid during significant droughts, leading them to treat nearly every drought as a humanitarian disaster.

Climate change has made infectious diseases more severe, say Moore et al., (2017) and Kagunyu, (2014) made a cryptic reference to this when she remarked that pastoralists need to band together to reduce danger. Evangelou, (2019) found that the primary causes of food insecurity among pastoral communities in ASALs like Kajiado were droughts, floods, and livestock diseases. According to Kagunyu (2014), pastoral communities in the ASALs struggle to sustain their assets due to frequent droughts and significant rainfall variability, and they also struggle to take advantage of good circumstances while they last due to a lack of timely early warning information. The present research looks at how climate change may influence people's access to drinking water, which is necessary for human consumption as well as that of domesticated animals.

According to Roser et al., (2016), pastors may lose livestock if the environment continues to deteriorate. According to Reid et al. (2020), there is also a high probability of sickness and malnutrition among this population. But their studies haven't shown how pastoralists might shield their way of life from the unfavorable effects of climate change. Pastoral communities in Kenya, according to Jandreau, & Berkes., (2016), have suffered the most from climate change. However, the study does not explore how individual families could adapt to new conditions.

2.5 Adaptation Strategies at Household Level

Pastoralists have historically been compelled to adjust to unfavorable environments (Elema, 2018). They often inhabit regions characterized by limited resources and severe weather, which renders them vulnerable to the effects of climate change. They have developed mechanisms to cope with a variety of environmental conditions (Belay et al., 2017), including the maintenance of drought-tolerant animals, consumption reduction, migration, and early warning systems. Adaptation strategies, encompassing both conventional and contemporary approaches, have gained worldwide recognition and innovation. In Nigeria during the early 1980s, pastoralists established associations to administer water collection points in accordance with household status

Migration, livestock division, restocking, and group alliances were among the traditional adaptation strategies identified by pastoralists in Southern Ethiopia, according to a study (Gebeyehu et al., 2021). However, it failed to demonstrate how each strategy mitigates the vulnerability of households, which is a gap to which this study intended to fill. Research findings suggest that pastoralists in Sudan, a country with a significant reliance on livestock for subsistence, employ well drilling as a

coping mechanism in response to water scarcity. According to a study by Kagunyu (2014), during periods of drought in Kenya, Borana pastoralists employ the practice of curling their livestock in order to augment their food supply. Additionally, the research unveiled that livestock mobility is diminished during periods of drought, resulting in decreased market prices and consequently no competitive edge. The objective of this research initiative is to examine the impact of livestock market price reductions on the vulnerability of households among Kajiado pastoralists.

Reid et al., (2020) posit that the reduction of climate variability necessitates the implementation of diverse management and adaptation strategies. One of the sustainable approaches to climate change adaptation is the consolidation of livelihoods. In addition, they assert that households have implemented diverse strategies in order to accommodate climatic variability and change. Walker et al., (2024) concurred that pastoralists must resort to a variety of mechanisms meant for mitigating negative issues associated with. Additionally, the study asserts that intervention by governments and other institutions is necessary to mitigate vulnerability.

According to research works conducted by ACTED (2011), numerous communities residing in the ASALs lack assets essential for livelihood and their capacity to cope was diminished throughout the 2009 drought. Gebeyehu et al., (2021). Corroborated this notion, further asserting that in light of the global emergence of novel climate change risks, local communities must enhance their conventional adaptation strategies. This study documents and analyses the current strategies in order to determine their effectiveness in mitigating household vulnerability. Included in the

analysis of adaptive strategies were wage labor, small business development, bead production, and agricultural production.

According to Wichern et al. (2019), Kenyan pastoral farmers have devised a wide variety of solutions to deal with the dangers posed by climate change and vulnerability. The International Panel on climatic Change (IPCC) (2014) defines adaptive capacity as "the capacity of a system to evolve in response to climate change." Furthermore, Kagunyu (2014) argues that coping techniques may be adding to environmental deterioration when pastoral lifestyles in East Africa become unsustainable. Mulo (2016) adds that by diversifying their sources of income, pastoralists may create one of the most successful adaptation methods. Input connection may be necessary for the successful implementation of adaptation strategies in Kajiado (Ombogo, 2013). The study's overarching goal is to delve more into the question of whether or not, among the assortment of ranches in the study region, diversity successfully reduces vulnerability at the family level.

Mobility is a prerequisite for pastoralists to adopt as an adaptation strategy, according to Huho et al., (2023); however, he does not elaborate on the manner in which mobility mitigates vulnerability to climate variability. This study provides an in-depth understanding of how Maasai pastoralists in Kajiado manage their vulnerability via wage labour (Matsaba et al., (2021). Households employ various strategies to mitigate risk, one of which is wage labour.

Coachingism's most adaptive characteristic, according to Western et al (2020), is the monitoring of seasonal precipitation and vegetation growth patterns. This is an excellent illustration of the migration routes and strategies of savannas' fauna. Pastoralists employ a wide array of additional tactics in order to boost the survival

rate and productivity of their livestock, thereby reducing the vulnerability of households to environmental unpredictability. Risk sharing through the division of livestock among clansmen, acquaintances, and relatives residing in regions less affected by drought, paddocking, vigilant surveillance of livestock and environmental fluctuations, and the implementation of early warning systems are a few examples.

The Maasai have historically coexisted peacefully with wildlife, regarding some as "second cattle" due to the benefits they have provided during periods of severe drought, livestock malnutrition, disease, or predation (Western et al., (2020). Historical practice has involved the utilization of animal behavior analysis to forecast meteorological conditions and astrological occurrences (Anghileri et al., 2024). They trade their livestock for alternative sustenance sources and establish themselves in close proximity to water sources. By implementing these tactics, pastoralists, including the Maasai in the Amboseli ecosystem, have been able to maximize their rangeland utilization and productivity. Nevertheless, the impacts of climate change have surpassed the capacity of both ecosystems and human beings to endure. Consequently, the pastoralists' indigenous knowledge has ceased to be relevant (Moyo et al., 2023). In addition, Macharia et al., (2020) notes that the indigenous knowledge of marginalized pastoralists is unlikely to be useful and that the magnitude of future climate threats will likely exceed their capacity for adaptation.

Abate (2016) found that some traditional coping methods used by pastoralists in southern Ethiopia had lost their efficacy and were difficult to adapt elsewhere. Therefore, it is crucial to include contemporary adaptation strategies with traditional understandings and account for gender-based assumptions in order to overcome climate volatility Opitz-Stapleton et al. (, 2023). Kihila (2018) adds that if

communities are able to overcome the existing constraints, sustainable indigenous practises can enhance the management of the negative consequences of climate unpredictability. Rahmah & Sulistyono. (2024). suggest using indigenous knowledge when mobilizing resources since many projects fail to acknowledge the community's resources for indigenous knowledge. Indigenous wisdom becomes irrelevant as a result of acculturation and Western influence. It is crucial to create documentation strategies and databases sensitive to cultural differences in order to preserve indigenous knowledge. Furthermore, it will be beneficial to combine scientific and indigenous coping methods through culturally sensitive technology transfer in order to address the increasing severity of climate risks.

Whether or not climatic variability has a significant effect on pastoralists is conditional on a number of factors, such as the availability of alternative sources of income, the age of household heads, the number of dependents, the prevalence of illiteracy, the availability of early warning information, the nature of the workforce, and the state of existing institutional structures (Leal et al., 2020). To what extent pastoralists are able to adapt to climate change depends on social aspects like education and food security, economic factors like per capita income, and physical features like natural resources. Their instigation of unfavorable conditions severely limits the ASALs' capacity for adaptation (Duguma & Heliyon 2022). Security in Mobility recommends establishing frameworks for resource sharing, building water basins and boreholes, mapping natural resources to facilitate sharing, ensuring safe migration, and encouraging peaceful dialogue between warring tribes to lessen the likelihood of conflict. Afforestation and replanting are viable options for the ASAL's

dry ecosystems. Trees provide several benefits, including reducing desertification and increasing land cover (Becerril-Piña, & Mastachi-Loza(2021)

To adapt to climatic unpredictability, pastoralists must surmount both internal and external challenges. Disputes with neighboring communities regarding grazing land, water sources, borders, and agricultural expansion are examples of external obstacles (Moyo et al., (2023). Internal barriers to adaptive capability include familial disputes, the poaching of livestock, and vector-borne diseases. Additional external barriers encompass limited engagement in community affairs, insufficient coordination and policies by the government, restricted availability of financial support, information, markets, grazing land, veterinary services, illiteracy, knowledge, and skills, as well as veterinary services, water sources, and grazing land (Altieri, & Nicholls, (2017)..Moreover, historically, women have been the most susceptible group in times of famine and drought; therefore, societal norms and customs that allocate responsibilities and obligations to men and women hinder the development of exceptional adaptability (Omolo, et al., 2018).

Although many studies have examined the effects of climate variability on Pastoralists in Kenya, minimal studies have been done on how the same affects the Maasai Pastoralists of Amboseli Ecosystem in Kajiado County. This research gap limits our understanding on how temperature and rainfall patterns affects the availability of Water and pasture for this community whose main source of livelihood is pastoralism. Further It presses the need to investigate what adaptation strategies the community has continue to put in place so as to cushion them against risk of long drought, water scarcity and vulnerability of their livelihood in terms of available household income, malnutrition and resource based conflict. A study by Ombogo, 2013 for example

majored on how climate variability affects forage distribution in Kjiado County, without digging deep on how this affects livelihood in return a gap which to which this study has addressed with specific reference to Amboseli Ecosystem with Pastoralism being the main economic activity for residents.

2.6 Summary of research gaps

This study seeks to address the following research gaps:

- (1) Establish whether climate in southern Kajiado County has changed in a detectable manner during the last three decades. This information was lacking in the literature reviewed.
- (2) Determine how climate variability has influenced water and pasture resources, which are critical for the pastoralist lifestyle of the Maasai Community in Amboseli Ecosystem

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Overview

This section presents the methodological approaches utilized for gathering the desired research data. It includes an examination of the study region, covering information about plant life and soil, the sociocultural environment, land utilization, and economic engagements. Furthermore, it describes the research structure applied, the designated population, sampling methodologies, data collection protocols, measurement strategies, data analysis techniques, research instrument validity, and ethical concerns.

3.2 Description of the Study Area

Kajiado County covers about 21,292.7 square kilometres of land. The four sub-counties that make up Kajiado County are Kajiado East, Kajiado Central, Kajiado North, and Kajiado South. Ngong, Kajiado Central, Isinya, Loitokitok, Magadi, Mashuru, and Mashuru are the county's seven administrative areas. Counties that surround Kajiado County include the capital of Kenya, Nairobi, as well as Machakos, Makueni, Narok, Taita Taveta, and Kiambu. People and goods are leaving Nairobi and the surrounding regions in increasing numbers. Because of this influx of people, major metropolitan centres including Ngong, Kitengela, Ongata Rongai, Kiserian, Kajiado, Loitokitok, Namanga, Isinya, Sultan Hamud, and Ilbisil are seeing significant growth in terms of both economic activity and human habitation.

The Amboseli Ecosystem is found between 1° and 3° south latitude and 36° and 37° east longitude. Rombo, Kimana/Tikondo, Olgulului/Olararashi, Selengei, Mbirikani, and Kuku are among of the six group estates that surround Amboseli National Park. However, it is important to note that property subdivision has occurred in the vast

majority of these group ranches, reducing them to individual lots. It was necessary to use this nomenclature to identify groups for the purposes of this study and to facilitate their classification as group ranches. These group ranches have a total area of around 506,329 hectares (AEMP 2008-2018). There are only 1,117,840 people living in Kajiado County, with the vast majority making their homes in the county's major urban centres (KNBS, 2019). Maasai pastoralists are the original inhabitants of the county, although there are other populations from other parts of Kenya. As a total, the Amboseli Ecosystem is home to 191,846 people across 47,058 homes (KNBS, 2019).

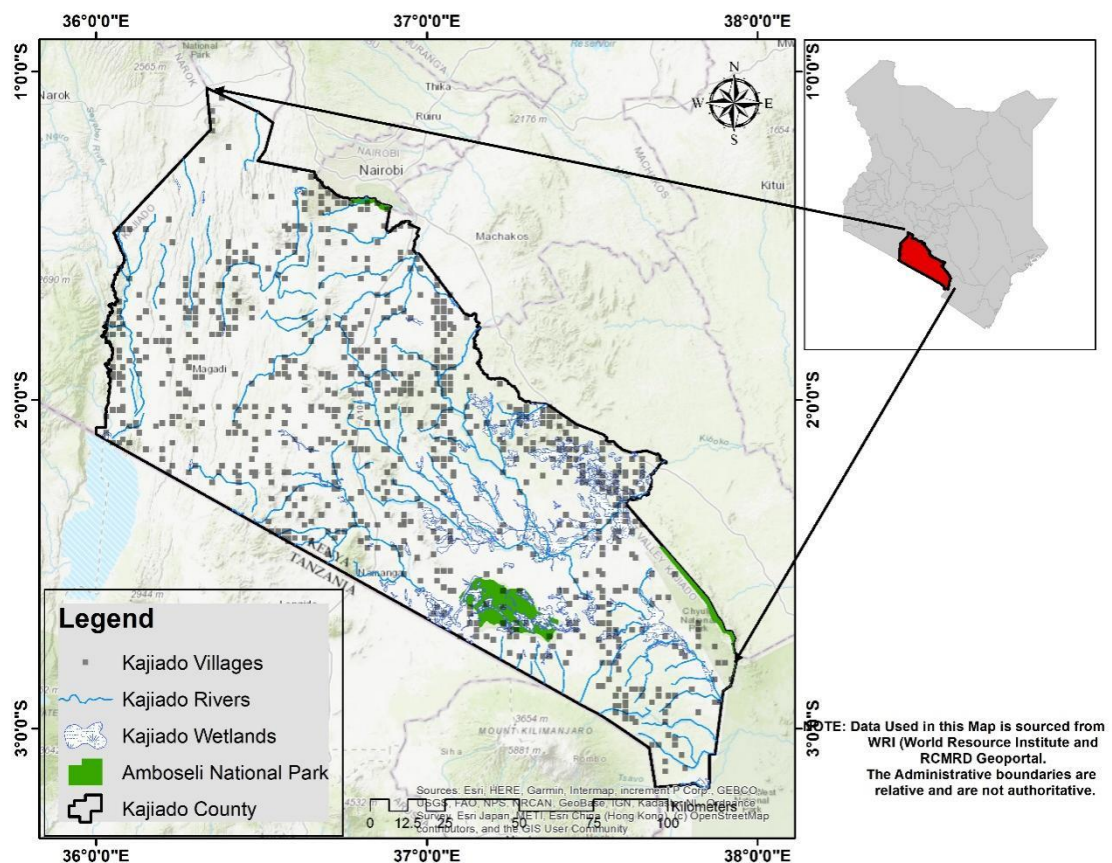


Figure 3. 1: Map of Kajiado County showing drainage pattern, key wetlands distribution of human settlements, Amboseli National Park and the rangeland hosting the group ranches (Source: RCMRD, 2021).

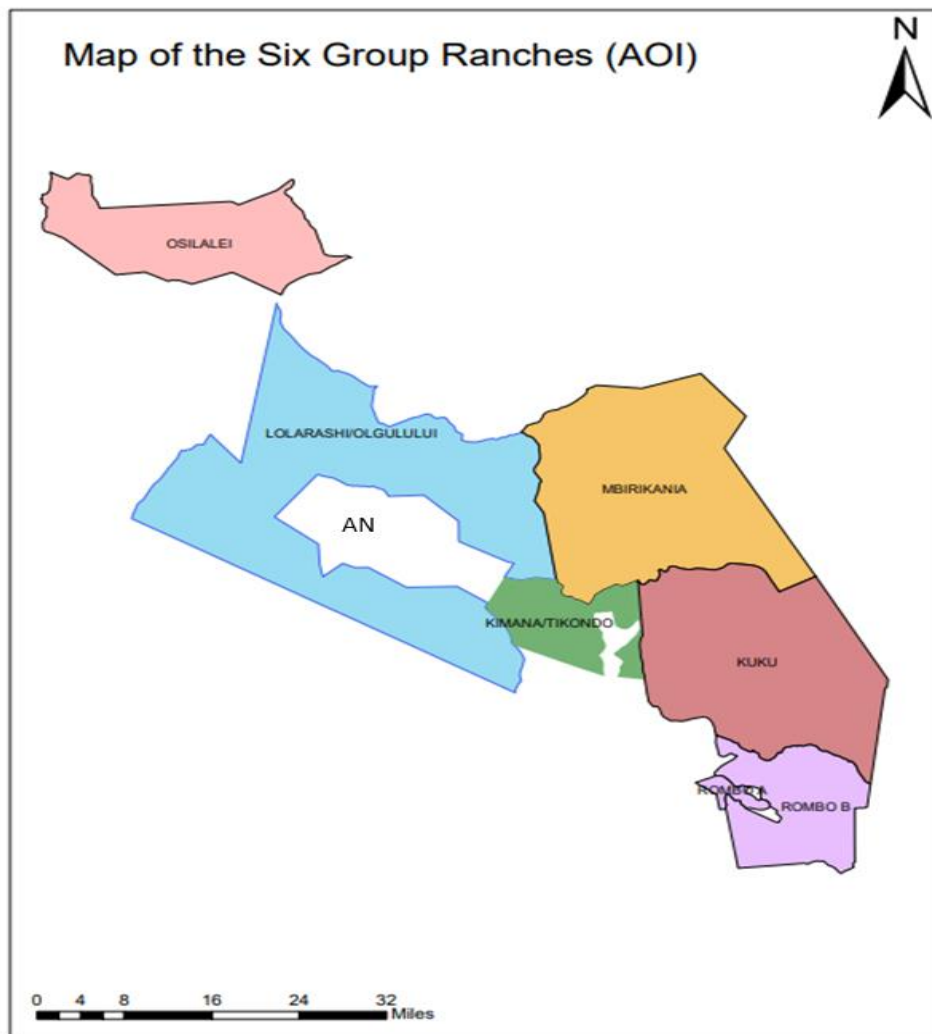


Figure 3.2 Map of six group ranches located around Amboseli National Park (Source: RCMRD, 2021)

3.2.1 Vegetation, Drainage and Soils

Within the region of Kajiado, Mount Kilimanjaro's presence on one side results in a climate characterized by low precipitation, creating a semi-arid environment. The major vegetation types are bushland, grassland and open woodland, which occurs along the valleys of seasonal rivers and marshes. The natural vegetation in the Amboseli Ecosystem is dominated by *Acacia xanthrophloea* woodlands in Lake Amboseli basin and *Acacia tortilis* dominates the rangeland surrounding the national

park. Seasonal marshes and permanent swamps are dominated by drought-tolerant grasses and sedges as well as *Cyperus papyrus* where surface water is deep and permanent. These vegetation types support provide pasture for large herds of livestock and wildlife within the Amboseli Ecosystem. This ecosystem is a unique in Kenya it supports more than 50 species of mammals and over 400 species of birds (Western et al., 2020). The national reserve ranks as Kenya's second most favored tourist attraction following the Maasai Mara. It has also been designated by UNESCO as a Man and Biosphere Reserve as it demonstrates peaceful coexistence between a community and their surrounding environment. However, some species of large mammals, such as the Black Rhinoceros, African leopard and the African lion are experiencing local extinction.

The Amboseli Ecosystem lies on porous volcanic lava, which was derived from the past volcanic activity on the adjacent Mount Kilimanjaro - the second tallest mountain in the world. Surface water from the mountain drains freely to underground channels and it emerges in numerous springs, some of which drain into swamps around Namelok and Kimana swamps. The Amboseli swamp and parts of the lake at the center of the national park are mainly maintained by ground water supply, which is augmented by rainfall. Surface water drainage is an important consideration as it influences pasture supply as well as distribution and movement of people, livestock and wildlife.

The soils in the Amboseli Ecosystem are primarily clay, which ranges from firm clay soils in topographic depressions to sandy clay soils in the semi-arid rangelands. In the rangelands, the soil is shallow and rocky and supports annual grasses, forbs and bushes. These are the main pasture for medium size livestock, such as sheep and

medium size wild herbivores, such as the Grant's Gazelles and Thomson's gazelles. Along the river valleys and other physical depressions, the soil is predominantly deep clay, which is fertile and supports riverine forest, woodland and permanent sedges and grasses. These are important foraging areas for livestock and wildlife (Fig 3.2), particularly during the dry season when pasture and water are scarce in the rangelands. However, due to increasing social and economic activities and overall effects of climate variability, the Amboseli Ecosystem remains fragile and highly susceptible to environmental change.



Plate. 3.2 (a) Cattle feeding in a group ranch



Plate . 3.2 (b) Yellow Fever tree forest at Oltukai

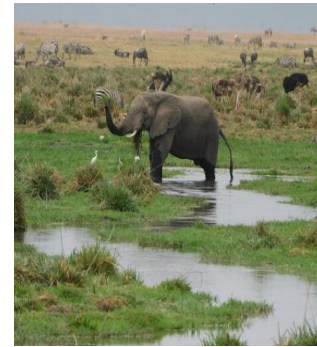


Plate. 3.2 (c). An elephant and other wildlife

3.2.2 Socio-Cultural and Economic Activities

The Maasai population represents one of the minority cultural communities in Kenya, which have been categorized as indigenous communities, because of its affinity to well-preserved pastoralist culture (AEMP, 2008-2018). This cultural distinctiveness has attracted tourists not only in Kajiado County but across all areas, where the Maa people have occupied in Kenya. Several stakeholders including Amboseli Ecosystem Trust, KWS and IFAW have an intention of improving enhancing the administration

of established cultural hubs through the implementation of training programs for operators of cultural centers in governance and policy questions to avoid having the recipients exploited in any way. Tourist operators are also being trained in different capacities to enable them acquire basic knowledge on how to promote cultural activities of the Maasai people alongside wildlife conservation in Amboseli Ecosystem.

Residing in the semi-arid rangelands of southern Kenya, where precipitation is infrequent and unpredictable, are the Maasai people, who predominantly engage in pastoralism, centered around animals. Their economic foundation hinges on this practice, and their way of life relies heavily on their ability to move their livestock. The Maasai have been able to sustain their nomadic lifestyle in this region due to a complex system of communal land ownership and a well-defined social structure. Access to pasture and water is determined by various factors, including belonging to a specific age group, family connections within pastoral regions, and membership in a clan or section

Most of the Maasai families are polygamous and therefore many homesteads are composed of multiple families (Museleku, 2018). Their social norms and obligations are highly regarded across age groups and gender. In the era of colonial rule in the 1960s, land holdings were formalized into group ranches (Western et al., 2020) However, livestock production has been experiencing uncertainties and challenges. . Livestock products are categorized as either private or shared goods. The staple Maasai diet is meat and milk. However, due to interaction communities from other parts of Kenya, their food is slowly changing. Accessibility to food and other basic needs was fully depended on Pastoralism in most of the group ranches.

The traditional system of communal land ownership and the associated social structure, which have been fundamental to the pastoralist Maasai way of life, are facing challenges due to socioeconomic changes and the uncertainties brought about by climate change. Factors such as population growth, the privatization and commercialization of communal land, climate unpredictability, and the broader economic development in Kenya are contributing to this strain. Currently, pastoralism remains the primary source of livelihood for the majority of Maasai families, as highlighted by Archambault in (2014).

Table 3.1 Human Population, Land size (ha) per Group Ranch

Group Ranch/Strata	Human Population (Households)	Size (ha)
Olgululi-Ololarashi	4452	147,050
Eselenkei	1232	74,749
Imbirikani	6631	122,893
Kimana/Tikondo	9261	25120
Kuku	11172	114712
Rombo	14310	38000
Total	47058	522,569

Source: adopted from KNBS, Census, 2019

3.2.3 Land Use and Economic Activities

In Kajiado County, pastoralism is the main economic activity, closely followed by crop growing. The Amboseli Ecosystem has been subdivided into three land use zones, namely: pastoralism, arable farming, and wildlife and tourism (Table 3.1).

According to AEMP (2008-2018), the purpose of zoning the area is to reduce conflicting land use practices while providing a sustainable environment for investment in other livelihood and income generating activities approaches that are in alignment with the social and economic preferences of the inhabitants

Table 3.2 Land Use Zones in Amboseli Ecosystem

Land use zone	Zone description	Land use objective
Livestock Production	Land that is neither under agriculture nor conservation activities Land elevation (1500-2000 meters above sea level)	Livestock production mainly through pastoralism
Arable farming/Crop growing	Land that under irrigation or rain fed agriculture at the base of Mt. Kilimanjaro Land elevation (2000 meters above sea level)	Food production and other marketable crops
Wildlife and tourism	Amboseli National Park, as well as established and planned community wildlife initiatives on concession areas and existing visitor accommodation facilities Land elevation (1500-2000m above sea level)	Wildlife Conservation and tourism, including cultural homes, bead work, tourists' entertainment

Source: Adopted from AEMP (2008-2018, (2020-2030)

The local people relies mostly on traditional pastoralism as their main source of sustenance, which occupies the majority of the environment. These regions are seeing significant population expansion as a result of immigration and the overflow of people from areas with strong agricultural potential (Western et al., 2020). As a result of alterations in the terrain in Kajiado, people are gradually transitioning from conventional livestock rearing to alternative non-traditional businesses (Koech et al., 2020). Nevertheless, several studies have demonstrated that pastoral livestock production in arid and semi-arid lands (ASALs) is the most efficient and effective form of production. Due to high demand for input, it is the most appropriate economic activity given the present dynamic climate and technical advancements (Museleku, 2018). According to the Kenya National Census, 2019 Kajiado County has a livestock population as follows: Cattle 698226, sheep 1,087,199, goats 1,284,712, Poultry 219,365 Camels 900 and 26,228 donkeys.

The area used for agricultural cultivation includes both privately held property and communal land that is part of crop irrigation schemes located at the base of Mt. Kilimanjaro. Crop cultivation yields better profits in comparison to other uses such as pastoralism and tourism. The wildlife tourism zone include the Amboseli National Park and designated areas for wildlife concessions. These regions feature various tourist lodging options like as tented camps and lodges, traditional residences, and locations for bead craft activities. The area is distinguished by abundant wildlife populations, making it very appropriate for tourists. This area has an average annual precipitation of 400mm and mostly depends on groundwater as its water source.

The land sub-division in Kajiado County during the early 1980s has resulted in sedentary lives predominantly dependent on a cash-based economy (Museleku, 2018).

Furthermore, this property subdivision has engendered ongoing conversations between landowners who are eager to sell and potential buyers who are willing to purchase the land. This circumstance has drawn a substantial number of heterogeneous land investors and settlers from various regions of Kenya and outside. Furthermore, individuals from the indigenous population, as well as people from diverse ethnic origins, have utilized land title deeds as collateral in order to get loans. However, this practice has resulted in a decrease in available grazing land, as it has been converted for alternative purposes.

3.2.4 Climate and Topography

The Amboseli Ecosystem maintains an average temperature of 21.6 °C, with an annual precipitation of approximately 400 mm. November stands out as the month with the heaviest rainfall, recording 209 mm. In contrast, the period from June to October experiences the lowest precipitation, averaging just 46 mm each year. July registers as the driest month.

The peak of precipitation takes place in April, with an average of 401 mm (15.8 inches). In terms of average temperatures, March experiences the highest temperatures, reaching around 23.4 °C (74.0 °F). Conversely, July marks the coldest month of the year, with temperatures averaging around 19.7 °C (67.4 °F). The Amboseli ecosystem falls under the Köppen-Geiger climatic classification Am. Precipitation varies by 355 mm (14 inches) between the driest and wettest months, while the annual temperature fluctuates by about 3.7 °C (6.6 °F) (KMD, 2018).

The formation of the Amboseli Lake Basin can be attributed to tectonic processes, leading to the subsidence of the terrain, creating a depression. This depression was further shaped by volcanic activity, also responsible for the formation of Mount

Kilimanjaro and other volcanic hills within the basin. Fracturing of the bedrock gave rise to fissures that serve as conduits for water to flow from the mountain and other hills, such as Namanga Hill, into the basin. The basin's topography is notably flat, and its loose, fine alkaline soil is prone to wind erosion, giving rise to dust storms. The name "Amboseli" originates from the Maasai term 'empusel,' signifying an extensive, open grassland.

3.3 Research Design

While utilizing empirical data, a researcher might apply a research design as a strategic framework to address their research inquiries. This study aimed to examine patterns in secondary meteorological data and use them to elucidate distribution patterns observed in socioeconomic surveys conducted among the residents of the Amboseli Ecosystem in Kajiado County.

To facilitate the integration of quantitative and qualitative data required to address the study issues, a mixed-method research design was employed. The design combines elements of quantitative research and qualitative research in order to answer specific research and integrate the benefits both quantitative or qualitative study designs. According to Kihara (2016), this design was suitable since it combines many designs, hence enhancing the validity of the results and compensating for any limitations of the combined designs.

Correlation design was also employed to investigate the relationship between the key variables measured during the study. The descriptive research design utilized open-ended questions and interview schedules to collect descriptive or categorical data. The socio-economic approach encompassed desk research, focus groups, interview arrangement, and questionnaire implementation. The study also utilized remote

sensing techniques and Geographic Information Systems (GIS) to examine the temporal and geographical distribution patterns of land use changes, pasture and water availability, vegetation indices, and climatic data.

The Kenya Meteorological Department provided the secondary data, while the primary data were collected through questionnaires and in-person interviews with key informants. The GIS remote sensing data was sourced from the Regional Centre for Remote Sensing, the Kenya Bureau of Statistics, the Kenya Roads Board database, the Kajiado County Integrated Development Plan, and other county publications.

3.4 Target Population

The target population primarily comprised all households of pastoralists' resident within Amboseli Ecosystem in Kajiado County. According to the 2019 census of KNBS, Amboseli Ecosystem had a total population of 47,058 households distributed in six group ranches from which a sample of 384 household heads was selected. The sampling unit for this study was the household head, which could be either male or female, depending on who was responsible for the chosen family. Key informants from relevant entities, who contribute to policy and resource management decisions purposively in the area were also purposively selected from Amboseli Ecosystem Trust, Trust for Elephants, Kenya Wildlife Service, International Fund for Animal Welfare, Big Life Foundation, and the departments the meteorological service and livestock development in Kajiado County. The selection of interviewees was deliberate, as they were chosen based on their direct or indirect roles with the pastoral Maasai community in the research area.

3.5 Sampling Procedure and Sampling frame

The six group ranches in the study area were each treated as a cluster from which a representative sample was drawn. Mayattas or villages were elected systematically in each group ranch in proportion to its size. Questionnaires, targeting adult household heads, were administered from a convenient household as the starting point and continued until the desired sample size for the group ranch was achieved. Interviews were conducted with one or two respondents from each of the main organizations operating in the Amboseli Ecosystem and at the county headquarters in Kajiado Town. The key informants were selected based on their direct or indirect interactions with livestock, wildlife or tourism in the ecosystem.

3.6 Sample Size Estimate

To ensure the valid application of inferential statistical methods, it's imperative to have an ample sample size that encompasses all the characteristics of the target population. In this context, the following equation, as recommended by Kothari in 2004, was utilized to calculate the required sample size and give a true representation of the Amboseli Ecosystem's target population:

$$\text{Desired sample size, } n = \frac{N}{1+N(e)^2} \quad (3.1)$$

Where

n = Desired sample size,

N= Targeted population size,

e = acceptable margin of error

Applying the formulation to actual data at 95% confidence interval or 5% probability of encountering an individual without the desired attributes in the population:

The desired sample size, $n = \frac{47,058}{1+47,058 (0.05)^2} = 374$ individuals (3.2)

Accounting for the possibility of people's income means decline in participating or dropping when survey was going on, the research sample was increased by approximately 3%, which was equivalent to an additional 10 households. Thus, the sample size used in the study rose to 384 household heads. This sample size was adequate for this study as the population of residents was sparsely distributed in the study area.

Sampling frame

According to Kothari in 2004, the sample size for each stratum should be proportional to the population size of that stratum. To accommodate respondents from various group ranches and different key informant categories, the following sample frame formula was employed to determine the proportional allocation of the sample to each group ranch or stratum: The formula was applied because population distributed differed across group ranches. The formula below ensured each group ranch got the correct proportion based on its population in terms of households.

$$P_i = (N_i / N) \text{ where;}$$

P_i = proportion of population included in stratum i ,

N_i = Population size of the strata 1

N = total population of the study area

For the purpose of sampling, n_i represents the proportional sample size allocated to each of the six group ranches (Table 3.3).

Table 3.3 Sampling Frame

Group Ranch/Strata	N₁	N	P₁ = N₁/N	n	n₁ = P₁* n
Olgululi-Ololarashi	4452	47058	0.0946	384	36
Eselenkei	1232	47058	0.0262	384	10
Imbirikani	6631	47058	0.1409	384	54
Kimana	9261	47058	0.1968	384	76
Kuku	11172	47058	0.2374	384	91
Rombo	14310	47058	0.3041	384	117
Total	47058				384

3.7 Research Instruments

Research tools were designed to collect information from various categories of participants. The data collection methods employed in this study included questionnaires and interview schedules with key informants.

3.7.1 Research Questionnaires

The survey responses of the selected individuals served as the primary data source. The questionnaires were administered to the respondents by the Researcher. The questionnaires had five sections, asking about household demographics, pastoralism as a means of livelihood, climate variability indicators, the effects of climate variability on pastoralism, household adaptation strategies, and the efficacy of these strategies in reducing livelihood vulnerability. The questions were both multiple-choice and free-form. In addition, the researcher rated respondents on a Likert scale

(see Appendix I) to find out how they felt about the impact of climate change on pastoralism.

3.7.2 Focus Group Discussion

The focus discussion group comprised a cohort of ten to twelve persons who possessed knowledge of the study area and were well-versed in the topics of climatic variability and its impact on livestock and livelihood activities. The participants were provided with structured questions to direct their conversation and responses on topics such as climatic variability, pastoralism as a livelihood source, and adaption techniques. The sitting arrangement for each FGD was a round table so as to actively engage all participants. The questions presented to the FGDs were selected from the questionnaire.

The selection of participants for the focus group discussions (FGDs) was done using purposive sampling. Four focus group discussions (FGDs) were conducted separately for each gender to allow them express their views freely. This was also done to ensure availability of the participants was taken into consideration since men and women were available at different times depending on their daily engagements. The purpose of holding FGDs was to elicit more information, perspectives, and viewpoints pertaining to the subjects being examined. The findings obtained from the Focus Group Discussions (FGDs) were categorized into themes in order to enhance the replies provided in the questionnaire or to provide clarification on contentious matters. The discussions in the FGDs were mostly focused on climate variability and pastoral themes.

3.7.3 Key Informant Interview

The interview guide covered a wide range of topics, including the organization's background, their interactions with pastoralists, their contributions to pastoralists' livelihoods, their knowledge of adaptation techniques, and the effectiveness of these strategies in reducing vulnerability, especially at the household level. The study placed a significant emphasis on expert knowledge provided by relevant organizations operating in the research area. As a result, experts were intentionally selected to contribute to the depth and breadth of the collected data, enhancing the research by incorporating their specialized insights.

3.8 Pilot Testing of the Research Instruments

A preliminary investigation was undertaken at the study area in April 2021 to assess the suitability of the questionnaire content. The purpose of the pilot study was to determine whether the questions were understandable to potential participants, estimate the amount of time needed to finish the survey, and make any required adjustments to the survey. To facilitate the testing of the research instruments, a 10% subset of the group ranches was selected from the target population. Mugenda and Mugenda (2012) recommended the selection of this subset to function as a representative sample size. The residences that participated in the pilot study were omitted from the primary survey.

3.9 Validity of the Instruments

The Content Validity Index (CVI) quantifies the degree to which a survey instrument assesses the specific dimensions that it designers intend to evaluate. Concerning the content validity of the instruments, the university supervisors and other authorities

were consulted for their perspectives and feedback. The participants were instructed to classify each item as either Relevant (R) or Irrelevant (IR) in the questionnaire. Assigning the proportion of specialists who deemed an item pertinent yielded the content validity ratio (CVR). The calculation of the Content Validity Index (CVI) involved averaging the CVR values pertaining to all the primary concerns addressed in the questionnaire survey. The present investigation employed the subsequent uncomplicated formula to calculate the Content Validity Index (CVI).

$$CVI = \frac{(TR1 + TR2)/2}{Total\ Items} \quad (3.3)$$

In the provided formula:

CVI = Content Validity Index

TR1 = the total of all items considered relevant by the initial group of experts

TR2 = the total of all items considered irrelevant by the second group of experts

The CVI index has a maximum value of one, and the closer it is to one, the higher the content validity of the survey tool. Salim et al. (2018) suggested that a Content Validity Index exceeding 0.5 is adequate to consider an instrument valid.

3.9.1 Reliability of the Instruments

This involved the allocation of the instruments to the participants. The data obtained from the instrument were entered into the SPSS programme, which then performed an internal consistency check on the data. The instruments were subjected to a reliability test during the pilot phase to determine the consistency of the results given. If the value of r is more than 0.70, it indicates a strong level of internal consistency

(Viladrich, 2017). The reliability test yielded an r-value of 0.712, indicating a high level of dependability for the devices.

The dependability of a measurement refers to the consistency and stability with which an instrument evaluates a certain idea. It helps in assessing the quality of a tool (Shanmugam et al., 2018). To improve the reliability of the research instruments, the following steps were taken in their consideration: ensuring that each question was clear and concise to avoid any bias in the responses; placing more difficult questions towards the end of the survey; reducing the number of open-ended questions; designing response scales to increase the range of responses, thereby ensuring meaningful statistical analysis of the data; and making sure that the questions addressed important issues.

When determining dependability for these devices, Cronbach's alpha was subsequently utilized (Viladrich, 2017). The elimination approach utilized an interterm correlation matrix to identify non-essential elements that did not significantly contribute to alpha. Cronbach's alpha is particularly valuable for evaluating the internal consistency of a scale. It offers a distinct and quantifiable measure, and only takes one administration. This method is especially applicable for multi-item scales at the interval level of measurements (Mugenda & Mugenda, 2012). As per this book, the minimum need for this study was a dependability coefficient (Rho) of 0.7 or above. Reliabilities below 0.6 are typically considered to be below standard, while those between 0.70 and 0.80 are considered acceptable, and those above 0.80 are considered satisfactory (Shanmugam et al., 2018). The content validity was considered sufficient since the items included in the study were created after a thorough literature review and a pilot test.

Table 3.1 Reliability test

OBJECTIVES	MANAGERS	
	Cronbach's Alpha	Number of Items
Information on pastoralism as a source of livelihood	.712	15
Climate variability indicators	.857	8
Climate variability impact on pastoralism as a source of livelihood between the years 1989-2019	.920	23
Indicators of gender inequality	.849	16

As per the test results presented in Table 3.3, the Cronbach's reliability coefficient for all the topics addressed in the research objectives exceeded 0.70, which is the recommended threshold. Therefore, it can be concluded that the research instrument was reliable and suitable for further data analysis.

3.10 Data Collection Procedure

In April 2021, a preliminary investigation was undertaken at the six group ranches with a proportion of the sample size, in which research assistants were enlisted and research tools were tested. All of them were graduates who were well-versed in the field of study and had a comprehensive understanding of the Maa language. The results of the pilot research were utilized to modify the questionnaire and data gathering strategy in order to enhance its realism. A GPS was used to designate the target settlements in the six group ranches, and a mobility plan was created. A letter of introduction was acquired from the Graduate School of Kenyatta University, and a research permission was received from NACOSTI. In addition, authorization for the

gathering of data was requested from the office of the Kajiado County Commissioner (Appendix VII).

Data collection commenced in July 2021 and concluded in May 2022. Throughout the study, the researcher and trained assistants utilized cars or motorcycles to go to the designated villages and homes for conducting interviews or administering questionnaires. The assistants aided in identifying the accessible routes to various homestead since they had knowledge on the area's terrain given they too were residents. The participants also recorded their replies in the serialized questionnaires but in instances where respondents were illiterate the researcher filled the questionnaires as well as coding and transcription for the FGDs.. The sample technique was devised to obtain answers from the intended participants throughout both the dry and wet seasons. This involved collecting opinions from participants during the short rainy season in September, October, and November, as well as when rain fell heavily within the month March, April, and May. Supportive data regarding the study were collected using a notebook, pen, and camera. This included firsthand observations, explanations of important concerns, and photos of locales and occurrences. Literate Participants were provided with questionnaires to complete independently using a pencil. A pedometer watch, a gadget that detects body motion and calculates the number of steps taken, was utilized to find the sampled houses.

3.11 Data Management and Analysis

Thoroughly analyzing the questionnaires to identify any missing information and eliminate any discrepancies in data collection. The data was classified based on the study's goals. The survey's quantitative data was organized into understandable categories in the form of tables. Diverse statistical software packages were utilized.

An Excel spreadsheet was utilized to facilitate the segregation of data. This procedure was conducted to enhance the efficiency of exporting data and deriving significance from it. The pictures taken from the field, together with the information recorded in the field notebook, were assembled to augment the primary data gathered via surveys, focused group discussions, and interviews.

Data cleaning was performed to eliminate errors of commission or omission from the raw data. The purpose of coding was to ascertain the research variables of the study. This procedure facilitated the reduction of material into concise summaries and its organization for effortless comprehension analysis was conducted to examine the fundamental attributes of quantifiable information to determine or confirm the information's essential properties for data and identify any modifications that could be needed to normalize the distribution of the raw data. Additionally, acceptable statistical techniques to be employed were determined. Data that did not require statistical modification were summarized using descriptive statistics.

Independent data sets were derived from the variables of interest, and inferential statistics were then used to compare the data. The quantitative data were subsequently analyzed using one –way Analysis of Variance (ANOVA) to partition the data into several components. A correlation analysis was conducted to assess the strength of the links between variables that fluctuate together, and to identify statistically significant correlations in the data. The study conducted multiple linear regression analyses to evaluate the impact of independent factors on the dependent variable(s). That is how rainfall patterns and temperature affected water and pasture availability and distribution which were further tested using NDVI. At the household level this was used to test relationship between Rainfall and Temperature with availability of

milk, animal market prices, herd size, animal production. The formula below was applied

$Y = a + b X$, as discussed in section 4.10

The qualitative data were subjected to content analysis through the examination of photos and images. Various statistical methodologies and image analysis techniques were necessary for each sort of qualitative data collected. The next section provides an elaborate explanation of the many methodologies employed to analyze distinct classifications of picture data. A significance threshold of 5% was utilized for all the statistical tests performed.

3.11.1 Analysis of Seasonal Climate Variability Data

Dry periods are common in Kajiado County from December to February, with lengthy rains from March to May and short rainfall from October to December. Lower temperatures describe June and July, whereas a lack of precipitation characterizes August. Many researchers have used this way of categorizing seasons depending on the months of the year (Atube et al., 2022 & Nicholson, 2014). Meteorological information, such as monthly averages, seasonal averages, yearly averages, and the climatological variation index for rainfall and temperature, were collected across a 30-year time frame. World Meteorological Organization (WMO) standards for analyzing long-term climatic trends and seasonal data informed the selection of the cluster periods (WMO, 2018).

The Mann-Kendall statistical approach was used to analyze the presence of a trend in monthly and yearly temperature and rainfall data in the Amboseli Ecosystem from 1988 to 2018. The Mann-Kendall test was used in combination with the XLSTAT program. The rainfall and temperature data collected from KMD were pre-whitened

before to the Mann-Kendall test. The tools ArcGIS10.6, SNAP, and ENVI 5.3 were used to estimate changes in water and pasture availability in the research region. Esri (2021) recommended using PCA to assess household vulnerability. Section 3.11.3 goes into great depth on how to use the formula. The vulnerability index was calculated for each selected household using the calculation proposed by the Intergovernmental Panel on Climate Change (IPCC) in 2014. ANOVA was used to measure the variability of temperature and rainfall in the study region, while regression analysis was used to evaluate and anticipate associations between connected variables. Climatic data were evaluated using the specialized tool XLSTAT (2012).

The Mann-Kendall statistical technique, developed by Mann in 1945 and Kendall in 1955, was used to examine changes in seasonal and annual rainfall and temperature within the study area. The non-parametric approach for trend analysis is acceptable since it is based on data ranks and is unaffected by outliers. The Kendall rank correlation coefficient (τ) measures the degree of similarity between correlation patterns and runs from -1 to 1. When the data trend is increasing, it assumes a positive value; when the data trend is falling, it assumes a negative value. The Sen Slope (S) in equation (4) is derived using the test program (XLSTAT 2012) and serves as an approximation of the median slope among all the slopes predicted between each pair of points in the time series, as proposed by Agarwal et al., (2021).

$$\text{Sen slope, } S = \sum_{i=1}^{n-1} \cdot \sum_{i+1}^n \text{sign}(T_j - T_i) \quad (4)$$

$$\text{sign}(T_j - T_i) = \begin{cases} 1 & \text{if } T_j - T_i > 0 \\ 0 & \text{if } T_j - T_i = 0 \\ -1 & \text{if } T_j - T_i < 0 \end{cases} \quad (5)$$

Where, T_j and T_i are the annual values in calendar years j and i , $j > i$, respectively. The Program the magnitudes of positive and negative differences as shown in equation (5).

Mann-Kendall statistical tests were conducted using Addi Soft's software (XLSTAT 2012). The hypothesis of no trend (H_0) was assessed at a 95% confidence interval for both the temperature and rainfall datasets. To compare the results obtained from the Mann-Kendall test, linear trend lines were created for each dataset using the Microsoft Excel 2016 program.

3.11.2 Analysis of Changes in the Pasture Resource

Throughout the research region, Maasai livestock includes cattle, donkeys, goats, and sheep. This varied herd forages on many types of natural pasture (grass, sedges, and shrubs). Grass is the primary food source for livestock. In certain cases, healthy bushes. There were several types of plants in the research region. The Amboseli environment was characterized by thickets, bushes, and other forms of vegetation. Pasture and water distribution were strongly reliant on rainfall, making them an excellent indication of climatic unpredictability and, by implication, household vulnerability. Various software's were used to measure plant cover and greenness (indicating palatability) in order to analyze the change in accessible natural pasture supplies.

The LANDSAT pictures were processed, analyzed, and shown using ArcGIS version 10.6. ArcGIS was also used to make maps. Simultaneously, same program was utilized to identify change at several epochs. The Sentinel images were edited and corrected using SNAP software. ENVI 5.3, on the other hand, was utilized to extract significant information from the photos obtained, assisting in the creation of a rich conclusion. This was utilized as (Viladrich, 2017) indicated. During the thesis writing process, I utilized Microsoft Office 2016 Word. The following subsections detail the digital image processing stages that were applied and employed in the identification of vegetation change in the research region.

3.11.2.1 Resampling

The digital photographs were changed and turned into suitable forms for this inquiry by the process of resampling. The technique provided data on samples of vegetation imaging. Diverse tactics were employed to surpass the constraints imposed by camera or picture geometry. The resolution of Landsat 5 and 8 photographs could be readily adjusted and obtained at a 30-meter resolution. In contrast, Sentinel images were recorded at a higher resolution of 10 meters, surpassing the resolution of Landsat images. The resolution of all pictures in this investigation was standardized.

The process of converting Landsat imagery from a resolution of 30 meters to a resolution of 10 meters led to an increase in the file sizes of the group ranch. In order to make up for this, the processing time for huge photographs is extended. The software ENVI was utilized. The procedure involved modifying the X-pixel and Y-pixel sizes using characteristics such as Pasture and other plants to perform layer stacking. Additionally, a bilinear resampling technique was employed to enhance the

reliability of the data extracted from the photographs. The Sentinel image was also resampled, increasing its resolution from 10 M to 30 M.

3.11.2.2 Layer stacking

Data from the Amboseli Ecosystem Landsat satellite were analyzed over a three-decade period, from 1988 to 2018, to improve the information included in several captures of the same area. Images were taken using several bands, and each sensor recorded numerous bands from the Amboseli ecosystem's six group ranches. These bands were used to form a composite picture that encompassed the whole Amboseli habitat.

Layer stacking was used to condense the chosen bands from the group to enable further processing. In the case of Landsat 4-5 and Landsat 8 photos from 1986 and 2000, bands 4, 3, and 2 were used for layer stacking. As shown in Figure 3.2, these bands were layered to create fade color combinations for the relevant satellite photos

The research concentrated on two Landsat rows, 060 and 061, as well as four Sentinel imaging blocks: T36MZE, T36MZD, T36MYD, and TDMYE. Both Landsat and Sentinel imaging encompassed the Amboseli habitat. The Amboseli Ecosystem was predominantly covered by the 169 route in row 061, with a slight extension into row 060.

Sentinel imagery documented various areas within the Amboseli ecosystem, including T36MYE, T36MZE, T36MZD, and T36MYD. The imaging process was conducted using ENVI 5.3.

While Landsat imagery overlapped primarily in a vertical orientation, Sentinel imagery exhibited both horizontal and vertical overlap. The Sentinel images

comprised four layer-stacked image files corresponding to the four blocks covering Kajiado South. To address potential data masking in some regions of the overlap area, seam lines were created.

Following the creation of seam lines, a seamless feathering technique was applied, and the resulting data was then exported to the project folder in DAT file extension.

3.11.2.3 Sub setting using Kajiado County Shape File

The process of sub-setting involved precisely extracting the necessary portion of the Amboseli ecosystem by means of cutting. The resulting downsized picture reduced both the processing time and storage space required. The photos of the six epochs were selected using a shape file of the Kajiado South Sub-county. The Amboseli Ecosystem border was utilised as a focused subset. The Amboseli Ecosystem area was extracted from the whole mosaic photos of the group ranches using imagery from Landsat and the 2018 Sentinel mosaic image. The file shape was obtained from the repository of Kenya Roads Board's shape file databases. The study focused on extracting the region of interest from the sub-county shape file and exporting it for the purpose of clipping. They are together.

3.11.2.4 Development of Image Classification Scheme

Classifying the image is aimed to categorize within the six group ranches of the Amboseli Ecosystem using remotely sensed data. Specifically, it involved the automatic classification of images from Olgulului-Ololarashi, Eselenkei, Old Kimana-Tikondo, Imbirikani, Kuku, and Rombo group ranches. For supervised classification, 90 training datasets were utilized for each cover class, including cultivated land, grassland, crop fields, and shrubland. Additional land categories included forested areas primarily located in the Kuku group ranch at Oloitokitok in

Mawenzi, areas designated for human habitation such as small towns and centers, and undeveloped land devoid of vegetation. Cultivated land and other vegetated areas consisted mostly of planted crops and shrub lands, with the limited chlorophyll spectral signature used to differentiate the group ranch values. Both supervised and unsupervised classification methods were employed to select samples based on the group ranches. The assessment also involved identifying areas characterized by sparse vegetation and grass throughout the sub-county. Spectral reflectance of the various plant cover classes was directly estimated using ENVI 5.3 software for image processing.

3.11.2.5 Normalized Differential Vegetation Index (NDVI)

The Normalized Difference Plant Index (NDVI) quantifies the amount of photosynthetically active radiation that is absorbed by chlorophyll in the green leaves of plant canopies. NDVI was employed in this study to quantify the degree of vegetation greenness throughout the study region. The presence of lush vegetation in the six group ranches was observed, leading to the conclusion that it may be indicative of the impact of climatic variability or its absence. The absence of vegetation was similarly utilized as a metric to assess the quantity of pastureland accessible for both cattle and wildlife, taking into account its distribution and availability. Never the less, not all vegetation were palatable. The NDVI was generated in this investigation using the NDVI tool included in the ENVI Toolbox. The application of NDVI for this particular study most preferred for temporal analysis as it allowed monitoring changes in vegetation cover within the study area over the three-decade period and provided insights into seasonal and long term trends. In addition, it does not limit the number of remote sensors as is the case in Enhanced vegetation index (EVI). NDVI was found

best in studying the effects of climate variability on vegetation cover as used by Ombogo (2013).

The near infra-red band and the red band were chosen as variable inputs throughout the research region to calculate the NDVI, which produces values ranging from -1 to 1. In the Landsat 4-5 TM and Landsat 8 ETM+ satellites, the near infra-red band was referred to as band 4. In the Sentinel 2B picture package, it was referred to as band 8. The Red band corresponds to band 3 in Landsat 5 and 8, and band 4 in the Sentinel picture package. The Normalized Difference Vegetation Index (NDVI) was computed on an annual basis over three decades. The grayscale representation in Figure 3.7 depicts values ranging from +1 to -1.

The NDVI values gathered from 1988 to 2018 were utilized to assess the variations in pasture availability for animals. NDVI readings were averaged for each month among the six group ranches, as NDVI is believed to have a strong correlation with rainfall patterns (Huang et al., 2021).

The inter-annual variability of NDVI patterns over a period of three decades was determined by computing the yearly values for the months of March, April, May, October, November, and December using equation (6). The calculation of NDVI was performed using satellite imagery in order to quantify the reflectance values for the RED and infrared bands. The study conducted by Ombogo (2013) aimed to assess the impact of precipitation on vegetation in the Amboseli Ecosystem over a period of three decades which was adopted for this study.

$$NDVI_{\sigma} = \frac{NDVI_{\sigma}}{NDVI_{\mu-1}} 100 \quad (6)$$

i. Density Slicing

This technique involved identifying areas that appeared uniform in tone across the six group ranches and was applied to generate NDVI (Normalized Difference Vegetation Index), as recommended by Liang et al. (2016).

ii. Remote Sensing

Using remote sensing, the study identified and tracked changes in the Amboseli Ecosystem's physical features. To evaluate how climatic variability affects pasture availability, this study focused on how vegetation cover changed over a three-decade span (1988-2018). In all of the six study ranches, the researcher created NDVI and density slices. Satellite images were gathered to track vegetation cover shifts.

Temporal Resolutions.

Geostationary satellites with temporal resolution were employed to determine the time difference between the years in the study area. Satellite imagery of the Amboseli ecosystem spanning a period of thirty years, from 1988 to 2018, was acquired to capture inter-decadal visible changes, following the recommendations of (Hamilton et al., 2016). This approach allowed for the analysis of changes in vegetation cover over three decades as well as inter-annual differences.

iii. Accuracy Assessment

The quality of the information obtained from remotely sensed data was assessed through accuracy assessment. This assessment could be either qualitative or quantitative and was conducted to verify the accuracy of the findings related to changes in vegetation cover, in line with the recommendations of (Olofsson, et al., 2014).

3.11.3 Vulnerability of Pastoral Maasai Households to Climate Variability

In this research, a range of vulnerability indicators were utilized to evaluate how vulnerable pastoralists were to climate fluctuations. These indicators were aggregated to create an index, following the approach recommended by Ayanlade, et al., (2023). Different indices were chosen to evaluate the vulnerability of households throughout the study area. To ensure that the standard deviation values of these vulnerability indices were comparable across the six group ranches, they were normalized, in accordance with the suggestion by Derbile et al. (2022). Additionally, principal component analysis was utilized to assign weights to these indicators, as proposed by Greenacre et al., (2022) The following formula was used to compute the numerical value for desired vulnerability index (I_j).

$$I_j = \sum_{i=1}^k b_j \left(\frac{a_{ji} - x_j}{S_i} \right)$$

(7)

Where:

I = the numerical value for index

b = Weights obtained from PCA

a = the exact individual indicator value

x = the mean/average value of the indicator

s = indicators' standard deviation.

Each household vulnerability index was calculated as per the equation suggested by the IPCC (2014) as follows:

$$V = AC - (E + S),$$

Where:

V = each household vulnerability index

AC = the index for adaptive capacity

E = the index for exposure

S = the index for sensitivity for the corresponding household.

The overall vulnerability model was applied as shown in equation (8):

$$V_i = (A_1X_{1j} + A_2X_{2j} + \dots A_nX_{nj}) - (A_{n+1}X_{1j} + A_{n+2}X_{2j} + \dots A_{n+n}X_{nj}) \quad (9)$$

V_i = the vulnerability index,

X_s = adaptive capacity element

Y_s = elements of sensitivity and exposure

A_s = the factor scores of each variable calculated using PCA.

The numerical values of X and Y were determined by normalization using their mean and standard error.

This study utilized an integrated technique, incorporating several variables including social such as the household size, gender, age and level of education, whereas economic indicators included household available income, alternative sources of livelihood such as crop farming, employment, bead making or small business enterprise. Environmental elements included drought, floods, animal diseases and forage availability. The three categories combined were used to develop vulnerability indices for individual families. This approach was suggested by Amendola et al., (2017) and applied by Tesso et al. (2018) and Derbile et al. (2022). The index suggestion was formulated according to the definition provided by the IPCC (2014),

which specifies that vulnerability should be assessed by taking into account the system's adaptive capacity, sensitivity, and exposure. In addition, the procedure followed in the selection of the indicators as suggested by Greenacre et al., (2022).

The examination of vulnerability used many methodologies, including socio-economic, biophysical, and an integrated approach. The research utilized a holistic approach that considered both socioeconomic and biophysical factors and variables. The socio-economic vulnerability approach focuses on analyzing the political and socio-economic status of individuals. The area displayed variations in household income based on criteria such as educational achievement, gender, affluence, healthy lifestyle choices, access to loans, information and technology, and social connections, among other factors. The aforementioned criteria formed the basis for varying degrees of vulnerability variation (Greenacre et al., (2022).

The socio-economic approach involved income-generating activities aimed at determining the adaptive capacities of people within households or communities within group ranches, depending on their inherent qualities. A drawback of the socio-economic approach is its exclusive focus on societal differences, disregarding the reality that societies differ not just owing to socio-political variables but also as a result of environmental or biophysical causes. However, this technique was suitable for assessing a household's ability to cope with climate-related shocks based on their specific activities. However, the socio-economic approach failed to include the existence of natural resource bases that may mitigate the adverse impacts of environmental pressures. This constraint was addressed by the implementation of the bio-physical technique, which involved the consideration of many additional factors, those that possess subterranean water, wetlands, and seasonal rivers have the ability

to endure drought by using these resources, unlike those that lack them (Zeleeke et al., 2021). Society's vulnerability arose as a result of institutional and economic transformations. Vulnerability arises when an adaptation strategy fails to cope with either internal or external influences. According to Lee et al., (2016), livestock accounts for 40% of the worldwide agricultural production value and plays a crucial role in supporting the livelihoods and food security of about one billion individuals. The biophysical method was the second strategy utilized. This technique aimed to assess the magnitude of adverse impacts that a certain environmental disturbance had on both social and biological systems. It is sometimes referred to as an effect assessment. This study employed this approach to examine vulnerability to natural hazards, namely prolonged droughts. The findings revealed that pastoralists were most affected in the years 2009 and 2000. The pastoralists incurred significant losses due to the loss of their animals. During periods of drought, there has been an increase in human wildlife conflict, as cattle and wild animals compete for limited pasture and water resources. Climate fluctuations, such as excessive precipitation, resulted in floods that led to the relocation of households, property destruction, and animal loss. An exceptional occurrence that was documented is the El Nino event of 1998. Climate fluctuations and geological disasters significantly contribute to the vulnerability of communities. Greenacre et al., (2022). used the term "risk-hazard approach" to refer to this method/approach. This strategy was used to examine the hazards associated with climatic variability. The research period identified several risks, including animal infections, potential human diseases resulting from ingesting products from infected cattle, and risks related with migration. Conversely, this approach focused on severe occurrences and ordinary social processes that influenced varying levels of vulnerability Zeleeke et al., (2021). The study examined social dynamics related to the

sharing of resources within the group, including water, pasture, and food. It was noteworthy that this community exhibited a sense of communal responsibility by offering assistance to those in need. The integrated approach was employed as a supplementary way for conducting vulnerability assessments. This approach included both the socio-economic and biophysical variables. The socio-economic factors considered encompassed the revenue derived from milk sales, animal sales, employment, bead manufacturing, and small commercial enterprises. This study examined the relationship between factors such as money derived from milk production and their impact on reducing vulnerability. The presence of dangers, such as prolonged droughts, significantly heightened vulnerability. In situations where households relied only on livestock for their livelihood, the impact was particularly severe, making it extremely difficult for them to recover to their initial position. The United Nations (2004) provides a comprehensive definition of a hazard as any occurrence, circumstance, or action that possesses the capacity to inflict harm upon an individual, a community, or the environment. The research conducted in the Amboseli ecosystem utilized an integrated method to comprehensively assess the extent to which various hazards posed risks to the area, encompassing human, economic, and environmental issues.

3.11.4 Climate Change Adaptation Strategies

A regression analysis was performed utilizing several factors to determine the adaptation measures implemented primarily to mitigate the impacts of climatic variability. A total of five predictor variables were utilized to execute the multiple regression model. The study used a Likert scale to collect respondents' thoughts. They were asked to indicate their level of agreement by deciding from options such as

"strongly agree," "moderately agree," "disagree," or "strongly disagree" in response to the items offered in the questionnaires. The regression analysis findings were anticipated to reveal the factors that contribute to variation. The model was also used to forecast the presence of a substantial correlation between climatic variability and the vulnerability of pastoral livelihoods.

The statistical method of one-way ANOVA was employed to assess the importance of the variables, such as the relationship between rainfall availability and milk production, this was done by comparing the amount of milk available for each household during rainy season vis a vie the amount available in drier seasons. The correlation between temperatures and market prices during the sale of cattle. The correlation tested what time period were the animal market prices were high i.e. between hotter or cooler periods. Additionally, the regression beta parameters and the t statistic were calculated to assess the model's efficacy in predicting the correlation between variables such as crop cultivation, employment, tourism, bead making, and small business enterprise, and their impact on reducing vulnerability at the household level. The statistical findings were used to make determinations about the null hypothesis at a significance level of five percent.

3.12 Ethical Considerations

The study followed research ethics by guaranteeing adherence to the highest standards of socio-economic research. Prior to the initiation of the research activities, a preliminary letter, specifying the identity of the researcher and the objective of the research, was acquired from Kenyatta University. Approval was also requested from NACOSTI, the governmental body responsible for granting and issuing research licenses in Kenya, as well as the County Commissioner's office in Kajiado Town.

Five research assistants underwent training to familiarize themselves with their respective tasks, and were provided with a clear explanation of the study's goal. The study ensured the voluntary involvement of participants and upheld the principles of anonymity and confidentiality. The purpose of this was to guarantee compliance with the concept of informed consent (Fort et al., 2017).

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

This section is segmented into five parts. These segments encompass: sociodemographic features of households within the Amboseli ecosystem, patterns in climate variability, livestock population trends, availability of pasture and water, and the impact on the community's livelihoods in the Amboseli Ecosystem, along with strategies for adaptation.

4.2 Household Demographic Information

The study had a total of 384 participants out of which 362 questionnaires were articulately filled thus the response rate with 59% being male and 41% being female (Table 4.1). The research had a higher proportion of male participants due to the cultural expectation in the Maasai community for men to assume leadership roles within the family. Additionally, male respondents were given preferential treatment in terms of educational opportunities compared to their female counterparts.

All age groups were well represented in terms of the respondents' age distribution. The age group of 20-30 years had 48 respondents, accounting for 13.3% of the total. The age group of 31-40 years had 100 respondents, representing 27.6%. The age group of 41-50 years had 83 respondents, making up 22.9%. The age group of 51-60 years had 81 respondents, comprising 22.4%. Lastly, the age group over 60 had 50 respondents, accounting for 13.8%. A single individual from each home was questioned. The results indicate that the age group between 31 and 40 years had a higher proportion of responses, perhaps due to their greater availability. Moreover,

the majority of them possessed the ability to read and write, and enthusiastically engaged in many communal activities.

There was a notable disparity in the educational attainment between males and females. Approximately 17% of males had received education up to the elementary level, while the corresponding figure for females was 18. Even though Male responders had higher chances of completing secondary education, many may not have pursued further education owing to factors such as poor academic performance, limited access to finances, or being tasked with the job of caring for their animals. Women in this demographic may have discontinued their studies or were marriage off after high school, resulting in a lack of further educational pursuits. Among graduate-level participants, 23% held a certificate, with 12% having a diploma and 11% holding a university degree. Of these participants, 13% were male and 10% were female graduates. -

The number of illiterate individuals among the Maasai population in the Amboseli Ecosystem was primarily found to be high among the elderly and middle age groups especially women. On average, every household had at least one member who had attained Kenya Certificate of primary Education. The percentage of respondents with no schooling among the youngsters was at 4.1%, conversely, 37.8% reported having completed secondary education, whilst 22.7% claimed to have achieved a college-level degree. The latter group encompassed any participant who had enrolled in any higher education institution. Nevertheless, those with limited education and a dearth of significant job opportunities have been compelled to rely on subsistence cattle raising, a sector that is greatly influenced by climatic fluctuation.

Throughout the research, the majority of homes consisted primarily of a father, mother, and their children. Nevertheless, the number of individuals residing in each home ranged from two (2) in young families to seventeen (17) in polygamous households. The average number of individuals per home was nine (9), significantly above the national average of 3.5 and exceeding the UN's suggested maximum of 6 family members. The group is thus extremely susceptible to environmental fluctuations and food shortages.

The length of time spent living in the research region indicates a notable transition from a nomadic to a sedentary way of life. Only 27.6% of the respondents interviewed had been in the research region for more than 20 years. The percentage of individuals who had resided in the study region for 16-20 years was 15.5%. The responders who had lived for a duration of 11-15 years accounted for 15.5% of the total. The proportion of respondents who had resided in the region for 6-10 years was 16.3%, whilst those who had remained for 5 years or less accounted for 15.2%. Based on this research, it can be inferred that the majority of respondents were inhabitants in all six group ranches. The average duration of practise among pastoralists in this region was 13.2 years. The individuals who had engaged in the activity for the longest duration had a practise history of 24 years, while the beginners were those who had engaged in it for a period of 3 years.

Table 4.1 Demographic Characteristics of Respondents

Demographic Information							
Age Categories							
Age	20-30	31-40	41-50	51-60	Above 60		
Freq	13.3%	27.6%	22.9%	22.4%	13.8%		
Gender							
Gender	Male		Female				
Frequency	59%		41%				
Level of Education							
Cross Tabulation	Primary	Secondary	Tertiary	Graduate	Post Graduate	Non-formal	None
Frequency	10%	38%	23%	10%	9%	6%	4%
Duration Stayed (in Years) in Amboseli Ecosystem							
Duration	0-5 Years	6-10 Years	11-15 Years	16-20 Years	Over 20 Years		
Frequency	15%	17%	28%	21%	19%		
Household Size							
Statistic	Mean	Std	Max	Min	N		
Value	9.03	3.771	17	2	362		

Source Survey Data (2021)

4.3. Types and Trends in Livestock Numbers per household in Amboseli Ecosystem

As per the data in table 4.2, it's evident that the majority of pastoralists within the group ranches owned cattle, shoats (sheep and goats), and donkeys, making up 56.6% of the total. Another 40.1% had partial ownership of these animals, while 3.3% had

no livestock at the time of this study due to losses incurred in the previous drought seasons. Out of the respondents, only 21.5% were involved in cattle rearing, closely followed by 18.8% who kept goats, and 16.3% who maintained both cattle, shoats and donkeys. The information was supported by discussions held during the focus group at Rombo. In these discussions, one participant mentioned that they decided to maintain a herd of fewer than twenty (20) cattle primarily for milk production. This choice was influenced by the increased frequency of droughts in recent years compared to earlier periods.

Table 4.2 No. and Type of Livestock Owned by Households at Amboseli Ecosystem

Statistic	Mean	Std	Max	Min	N
Value	13.22	5.082	24	3	362

Type of Livestock	Frequency	Percent
Cattle	78	21.5
Shoats	68	18.8
Donkeys	59	16.3
All of the above	145	40.1
None of the above	12	3.3
Total	362	100.0

Source Survey Data (2021)

Source Survey Data (2021)

4.4 Number of Livestock Owned by Households to be considered wealthy

The response indicated that an individual is considered affluent in the region when they own a total of 830 livestock. This preference for a significant number of livestock is further clarified by the average number of cattle per household. By making this

comparison, it becomes evident that climate variability is indeed taking place in the region, since most households no longer had large herds of cattle, sheep and goats due to losses incurred during drought seasons in terms of livestock death, loss amidst migration or killed by Wild animals especially around the national park area and during water scarce seasons when wildlife were reported close to homesteads near water sources. This is apparent from the decrease in the number of animals currently being kept, as reported by participants in the focus group discussions held at Rombo, Kimana, and Imbirikani group ranches.

Table 4.3 Number of Livestock Owned by Households to be considered

Wealthy

	N	Standard Deviation	Mean
How many livestock should one own in this area to be considered wealthy	362	192.593	526.11

Source Survey Data (2021)

4.5 Perceptions of Climate Variability Trends from Respondent's

4.5.1 Rainfall and Temperature Patterns

The study gathered the respondents' perspective of the patterns of rainfall and temperature from 1988 to 2018 which was compared with KMD data to draw a rich conclusion. The findings were displayed in Table 4.4 below. Regarding temperature changes in the Amboseli Ecosystem, 73.7% of respondents reported a decrease in temperature, whereas 92.0% perceived a cumulative increase. This is in agreement with Kaoga et al., (2018) who noted that there has been a declining rainfall patterns in Kajiado sub-counties for thirty years with an exception of the North which recorded

high precipitation. On the same note, Bodagoye et al., (2014) also noted a declining rainfall trend in the area. On rising temperature trends this resonates well with records obtained from the Kenya meteorological department from 1988-2018.

Regarding rainfall patterns in the research region, 75.4% of the participants reported a decline in the amount of rainfall throughout the years, while just 3.0% believed it had increased. Based on this study, it can be inferred that most of the participants concurred that the quantity of rainfall in the Amboseli Ecosystem has been decreasing over the last thirty years. The responders provided instances of streams, marshes, and springs where water was formerly accessible but is now absent. Based on their observations over the years as well as what they could remember their observations resonates well with data collected from the Kenya meteorological department for the said period.

Regarding the incidence of drought, the majority of respondents (71.0%) concurred that the frequency of droughts has escalated during the last three decades, while a minority of respondents (5.5%) expressed a dissenting viewpoint. Pastoralists greatly depend on rainfall, which encompasses several factors such as time, quantity, intensity, and distribution. This meteorological feature significantly impacts their way of life and means of subsistence. The input, observations, and local expertise of the respondents are crucial in determining the presence or absence of climatic variability. It may be inferred that climatic variability may have contributed to a rise in the frequency of droughts in the study region.

The respondents were queried about the historical fluctuations in water accessibility for livestock and residential purposes from 1988 to 2018, based on their recollections and present observations. A significant decline in the amount of water accessible for

livestock and residential use was reported by 72.7% of the respondents. On the other hand, 19.3% saw an increase in water availability, while just 8.0% believed that it remained same. The local community has observed a drop in water availability, potentially linked to elevated evaporation rates, reduced accessibility to groundwater via shallow wells, and heightened competition for surface water supplies. Based on the observations and perspectives of the pastoralists, it may be inferred that climatic variability in the Amboseli Ecosystem has likely resulted in heightened water shortage.

There has been a decline in the incidence of animal illnesses throughout the years. This may be attributed to the accessibility of pharmaceuticals, the implementation of effective strategies in addressing livestock diseases, and the significant contribution of media outlets, particularly local radio stations like Mayian FM and Nosim FM, which regularly host livestock management sessions that cover the treatment of various livestock ailments. The percentage of those who agreed on a decline was 71.0%, while those who believed it rose accounted for 5.5%. The remaining 23.5% reported no change.

Table 4.4 Respondents Perception on the Rainfall and Temperature Trends Between the Year 1988-2018

	Decreased	No change	Increased
Based on your memories, and current observations, what is the state of Temperature variations between 1988-2018	51(14.1%)	57(15.7%)	254(70.2%)
Based on your memories, and current observations, what is the state of Rainfall patterns between 1988-2018	273(75.4%)	78(21.5%)	11(3.0%)

Source Survey Data (2021)

According to the data in Table 4.4, a majority of the respondents, namely 273 individuals (75.4%), agreed that there had been a decrease in rainfall in the Amboseli environment. Out of the total, 78 respondents (21.5%) reported no change, whereas 11 respondents (3.0%) reported an increased trend. According to Table 4.4, a significant majority of the respondents (254, or 70.2%) agreed that there has been a noticeable increase in temperature throughout the environment. Out of the total respondents, 57 (15.7%) reported no change, while 51 (14.1%) reported a declining trend. The information is corroborated by the secondary data acquired from the Kenya Meteorological Center in Nairobi, which indicates a consistent decrease in rainfall and a simultaneous increase in temperatures in the region. This is apparent from the regular and extended episodes of drought that were reported by respondents during the researcher's field trips.

When questioned about temperature fluctuations in the region, 73.7% of the respondents indicated a decrease, while 92.0% reported an increase. The number of

individuals who believed that the temperature increased was 263, while 29 individuals believed that it declined. Additionally, 79% of individuals believed that the temperature remained the same.

75.4 percent of respondents believed that the amount of rainfall dropped, while just 3.0 percent believed it rose. Based on this study, it can be inferred that climatic variability is taking place as a majority of the respondents agreed that the amount of rainfall received in the previous 30 decades has been declining.

Regarding the incidence of drought, the majority of respondents, 71.0%, acknowledged that drought frequency had increased over the course of three decades. Conversely, just 5.5% of respondents believed that drought occurrence had reduced. Based on this data, it may be inferred that climatic variability may have contributed to a rise in the frequency of droughts in the studied region.

The assessment of the water availability for livestock and residential usage from 1988 to 2018, respondents gave recollections and current observations. One of the questions posed to the respondents, here, the majority of respondents reported a 72.7% drop in the availability of water for livestock and residential use. Only 19.3% believed that the water availability was unchanged, while a mere 8.0% believed that it had grown. Based on this, we might infer that climatic variability has resulted in an escalation of water shortage. This phenomenon may be attributed to heightened water evaporation, diminished groundwater levels, and a significant reliance on precipitation.

Regarding livestock diseases, there has been a noticeable decline in their occurrence. This can likely be attributed to the availability of drugs and the application of professional methods in addressing livestock diseases. The media, particularly vernacular radio stations like Mayian FM and Nosim FM, also play a role by regularly

hosting sessions on livestock management, including the treatment of various types of livestock diseases. The percentage of those who agreed on a decline was 71.0%, while those who believed it rose accounted for 5.5%. The remaining 23.5% reported no change.

Regarding the influence of temperature on water availability, the majority of respondents expressed the belief that temperature had really affected the availability of water. The decline in water availability is a result of rising temperatures. This may be due to an elevated rate of evaporation.

Regarding the matter of pasture availability, the majority of respondents expressed a significant decline in availability, with 80.9% holding this view. Conversely, 19.1% believed that there had been no change in availability. This is supported from figure 4.6 4.7 4.8 and appendix XI on NDVI values

Based on the examination of temperature fluctuation and its impact on milk production, the majority of respondents expressed the view that higher temperatures had a noticeable influence on milk output. This ultimately impacts the level of family income by diminishing it, therefore resulting in vulnerability.

The responders' herd size is unaffected by temperature fluctuations. Based on this, we may infer that the quantity of cattle per family is influenced by several factors, except temperature. 82.3% of respondents believed that the size of the herd remained same, while 14.6% believed it declined and 3.0% believed it rose.

Regarding animal reproduction, the majority of respondents, accounting for 74.0%, believed that there was no change. On the other hand, 23.8% attributed reduced

reproduction to temperature variations, while a mere 2.2% believed that reproduction actually rose.

4.5.2 Rainfall Pattern between 1988 and 2018

The pattern of yearly rainfall in the Amboseli Ecosystem between 1988 and 2018 was inferred from the monthly data. As illustrated in Figure 4.1, the highest monthly rainfall of 9.342mm was observed in November 2006, while the lowest, 0.70mm, and was recorded in August 2000. These months were considered the wettest and driest, respectively. Over the course of 30 years, 17 years received below-average rainfall, four years received rainfall in line with the long-term average, and only nine years received slightly more rainfall than the long-term average. The annual precipitation pattern in the study area demonstrates a noticeable declining trend.

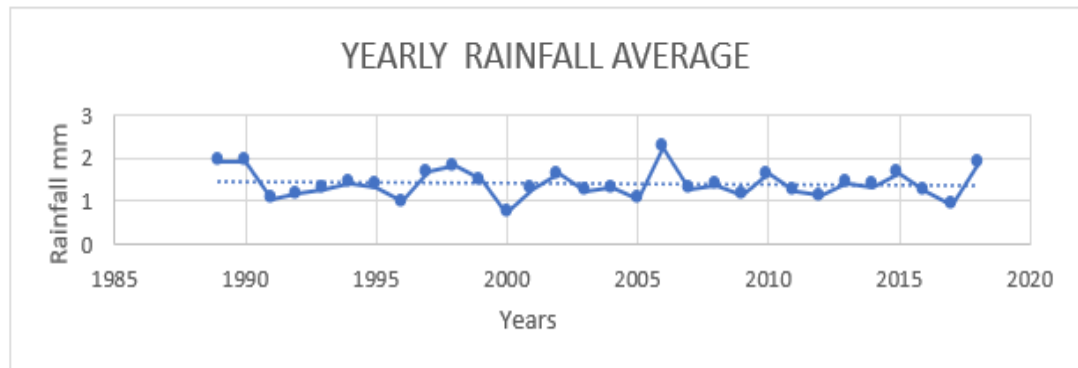


Figure 4.1 Yearly rainfall trends between the year 1988 -2018

Concerning the distribution of precipitation and the accessibility of grazing land, as rainfall decreased, the accessibility of pasture diminished, as reported by 67.7% of participants. Conversely, the same was seen in the opposite scenario. 8.6% of participants reported a rise, whilst 23.8% reported no change. Precipitation levels directly influence milk production. According to the respondents, changes in rainfall

patterns had a negative impact on milk availability, with decreased rainfall leading to a drop in milk availability, and increased rainfall leading to an increase in milk availability. 84.4% and 3.0% of respondents reported changes, whereas 12.4% stated that there were no changes. The survey revealed that whereas only 4.1% of respondents saw an increase in herd size during periods of increasing rainfall, a significant majority of 72.1% of respondents reported a drop in herd size during periods of decreasing rainfall. 23.8% of respondents said that the herd size remained unchanged. There seems to be a correlation between rainfall patterns and animal reproduction. According to 82.3% of the participants, reproduction rates are greater during seasons of heavy rainfall and lower during periods of drought.

According to the examination of market prices from the field survey, there was a positive correlation between market prices and rainfall because larger and healthier animals would be available during these seasons, which would benefit pastoralists. An interesting aspect of the market prices decreasing during the school opening season is that, regardless of whether it is the wet or dry season, the majority of pastoralists are compelled to sell their cattle in order to generate funds for school fees and other essential items for their children. The reason for this is that there will be an increased availability of animals for sale when the school begins. The analysis of the correlation between drought and water source availability revealed that water sources became scarcer during drought seasons, whereas they became more abundant during periods of increased rainfall. This data suggests that 64.9 percent of respondents agreed, 10.8 percent disagreed, and 24.3 percent reported no change. The drought's impact on pasture availability was evident, with 80.9% of respondents reporting decreased accessibility this season. Only 1.9% believed it was more

accessible, while 17.1% saw no change. Based on the analysis of the impact of the drought on herd size, 77.3% of participants acknowledged that it led to a reduction in herd size, whilst 21.3% reported no effect, and 1.4% anticipated an increase. Several plausible reasons for this phenomenon exist, such as the migration of livestock, mortality resulting from droughts, and individuals selling their cattle to mitigate the risk of drought-induced deaths. The occurrence of droughts seems to have impacted market pricing, with 84.3% of participants concurring that prices declined during periods of low rainfall, while 15.7% reported no alteration. The results above are true based on the survey data from respondent that corresponded with climate data obtained from the Kenya meteorological department for the period of study.

Table 4.5 Respondents’ Opinion on Temperature Variation Between The Years 1988-2018.

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Number of observations	30	30	30	30	30	30	30	30	30	30	30	30
Minimum	45	74	96	00	00	17	15	09	29	93	02	37
Maximum	10	75	37	07	54	01	57	03	91	58	42	66
1st Quartile	98	21	87	03	87	66	44	30	55	01	60	86
Median	90	41	63	22	53	30	91	66	57	71	93	49
3rd Quartile	35	87	05	82	06	84	23	78	13	55	81	77
Mean	84	57	59	90	54	79	93	26	07	42	05	79
Variance (n-1)	77	86	38	09	51	18	05	16	61	89	84	42
Standard deviation (n-1)	74	87	71	52	72	36	68	26	46	37	84	25
Variation coefficient (n)	1.1	0.7	0.6	0.4	0.57	0.7	0.7	0.98	69	0.6	0.8	0.2
Kurtosis (Pearson)	64	53	89	22	21	28	91	03	19	73	51	24
Standard error (Kurtosis Fisher)	33	33	33	33	33	33	33	33	33	33	33	33

Source Author (2022)

From 1988 to 2018, temperature trends in the six group ranches within the study area showed slight increases. The average temperatures in these group ranches had been gradually rising as shown in the table 4.5 above. On the other hand, respondent’s observation of rainfall fluctuations has been summarized in Table 4.6 below for a period of three decades. (1988-2018).

Table 4.5 displays the monthly descriptive statistics for the duration of the study, encompassing the mean, range, variance, standard deviation, skewness, kurtosis, total precipitation, minimum precipitation, and maximum precipitation. Based on the available data, the average monthly precipitation was at its lowest point in July

(0.093 mm), and at its highest point in August (3.405 mm). The monthly rainfall coefficient of variation (CV) ranged from 1.169% to 47%. September was the top of the coefficient of variation, which fell until April, when it reached its lowest point. The results of the study show that every month of the year exhibits a positive skewness score. This implies that there is a constant difference in the amount of rainfall at the beginning and end of the month. The range of the monthly standard deviation is 0.68mm to 1.78mm. Throughout the research period, the annual distribution of rainfall also deviates from the predicted normal distribution.

Table 4.6 Respondents’ Opinion on Rainfall Variation between the Years 1988-2018.

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Number of observations	30	30	30	30	30	30	30	30	30	30	30	30
Minimum	0.1	0.0	0.5	0.7	0.2	0.0	0.0	0.0	0.0	0.0	1.2	0.4
Maximum	7.1	3.5	7.7	6.1	2.9	0.5	0.3	0.4	1.1	2.5	9.3	7.4
1st Quartile	0.2	0.4	1.2	2.1	0.6	0.0	0.0	0.0	0.0	0.4	2.2	1.4
Median	1.1	0.9	2.3	2.4	1.0	0.1	0.0	0.0	0.1	0.5	3.0	2.3
3rd Quartile	1.6	1.6	3.4	3.8	1.4	0.2	0.1	0.1	0.2	1.0	3.6	3.5
Mean	1.3	1.1	2.6	2.9	1.1	0.1	0.0	0.1	0.2	0.7	3.4	2.5
Variance (n-1)	2.4	0.7	3.1	2.1	0.4	0.0	0.0	0.0	0.0	0.2	3.1	2.6
Standard deviation (n-1)	1.5	0.8	1.7	1.4	0.6	0.1	0.0	0.1	0.2	0.5	1.7	1.6
Variation coefficient (n)	1.1	0.7	0.6	0.4	0.5	0.7	0.7	0.9	1.1	0.7	0.5	0.6
Kurtosis (Pearson)	4.8	0.1	0.8	0.5	0.6	0.2	5.7	0.5	7.4	2.4	2.8	1.0
Standard error (Kurtosis Fisher)	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8

The consequential high temperatures lead to prolonged periods of drought, and in 2022, a survey conducted by the Kenya Red Cross categorized Kajiado County as one of the areas of highest concern owing to the continuous drought. Since 2021,

Amboseli inhabitants have seen sufficient precipitation, resulting in the relocation of most of their animals away from their residential dwellings. According to the Red Cross assessment, residents were traveling a minimum distance of 48 kilometers in order to obtain water for household use. The scarcity of food and the depletion of cattle have exacerbated this issue, prompting the government and philanthropists to intervene by providing food donations to the disadvantaged households.

4.5.3 Trends of Seasonal Rainfall

An examination of the seasonal precipitation patterns throughout the rainy season (March, April, and May) and the dry season (December, January, and February) revealed significant fluctuations over the span of thirty years (1988-2018). Short showers are often associated with lower precipitation compared to the rainy season. Nevertheless, it was discovered that the quantity of precipitation received during the height of the brief rainy season in November was nearly double the cumulative amount received over the extended rainy season in March, April, and May (M-A-M). The M-A-M component accounted for 36% to 47% of the total annual rainfall in the study region, with variations depending on the location of the recording station. The monthly precipitation pattern, as seen in Figure 4.3, exhibits a significant decline in rainfall from May to October. The bimodal rainfall pattern significantly influences plant production and, consequently, the availability of pasture. The interlude between the two precipitation cycles is a trying time for both humans and domesticated animals due to the scarcity of water and grazing land. In the year 2000, the Amboseli Ecosystem experienced its most severe hydrological drought, characterized by a near-total absence of rainfall throughout both the long and short rainy seasons.

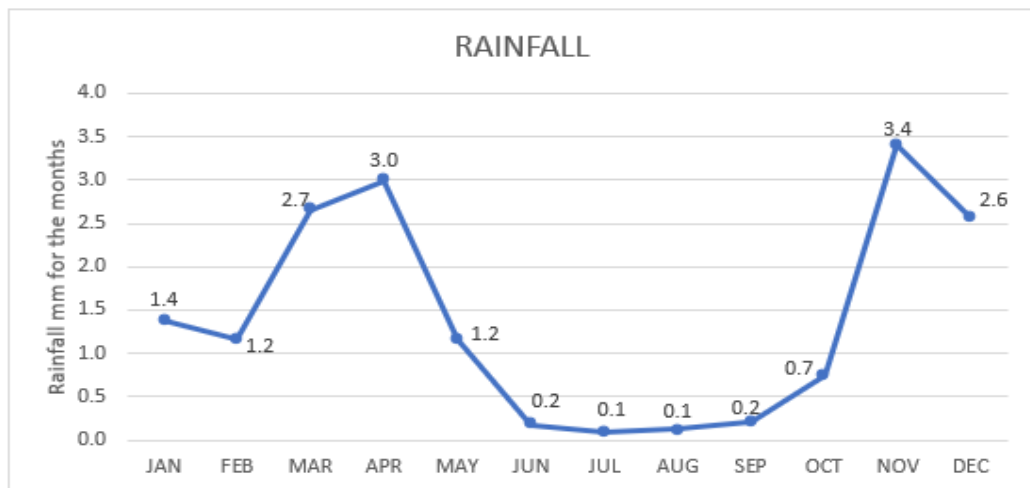


Figure 4.2 Average Monthly Precipitation Trend for the Period 1988-2018

The Amboseli environment saw below-average rainfall during the months of June, July, August, and September. April and November stand out as exceptional months throughout the research period due to their above-average rainfall in the Amboseli habitat. It was determined that the rainfall pattern undergoes significant variations, both in terms of quantity and timing, across relatively small distances and time periods.

Kajiado had a decline in seasonal rainfall throughout the studied time period. In general, the fluctuations in monthly, seasonal, and yearly rainfall indicate that rainfall patterns are very uncertain, leading to a lack of balance in the region's dynamics. The erratic patterns of rainfall throughout time create a basis for discussing the variability of rainfall in dry regions, and by extension, climate change.

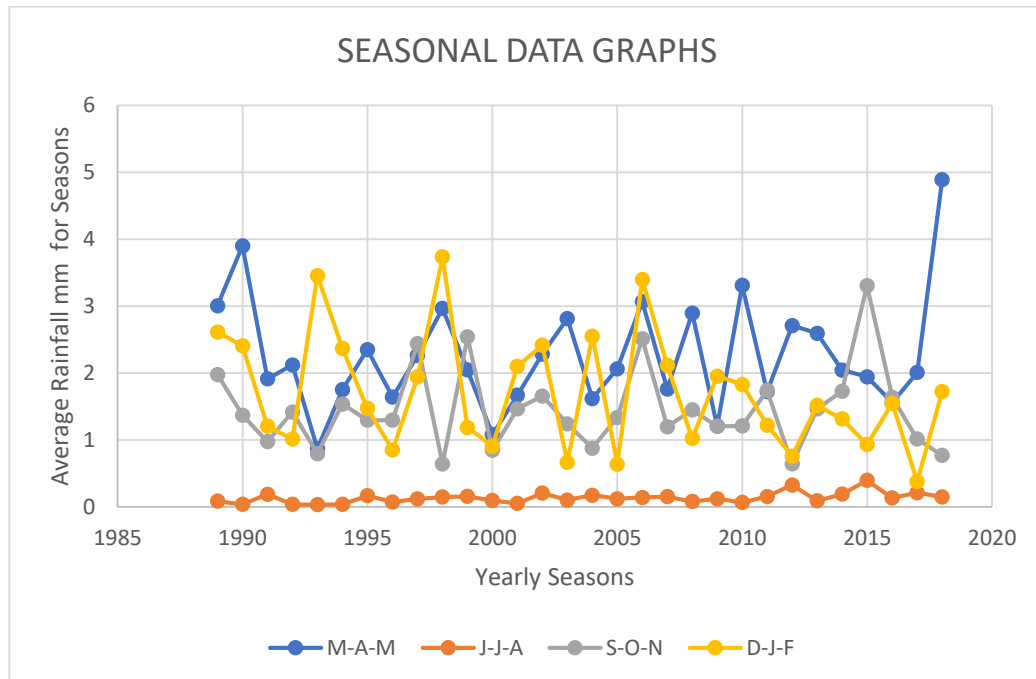


Figure 4.3 Annual Precipitation Trend for the Period of 1988 -2018

Source, Author (2022)

Based on the data presented in Figure 4.3, the years 2018 and 1990, around 28 years ago, saw the greatest mean annual precipitation (M-A-P). No major changes occurred during the dry season (June, July, and August), with the exception of small increases in 2013 and 2015. Precipitation in the months of September–November has generally been on the rise, with 2015 being the wettest year on record. There was a sharp drop from 2008 to 2018 throughout the winter months of December, January, and February. Since water evaporates more quickly when temperatures are high, no precipitation can make it to Earth's surface at that time.

The Amboseli Ecosystem's group ranches saw monthly rainfall totaling 1.12 mm or less in Mbirikani, 1.16 mm or less in Lolarashi/Olgulului, 1.33 mm or less in Kuku, 1.68 mm or more in Rombo, and 1.52 mm or more in Selengei. The vulnerability score found that among the group ranches in the Amboseli Ecosystem, Olgulului-

Ololarashi group ranch was the most vulnerable to climate variability as shown in fig.5.0 in section 4.9.2

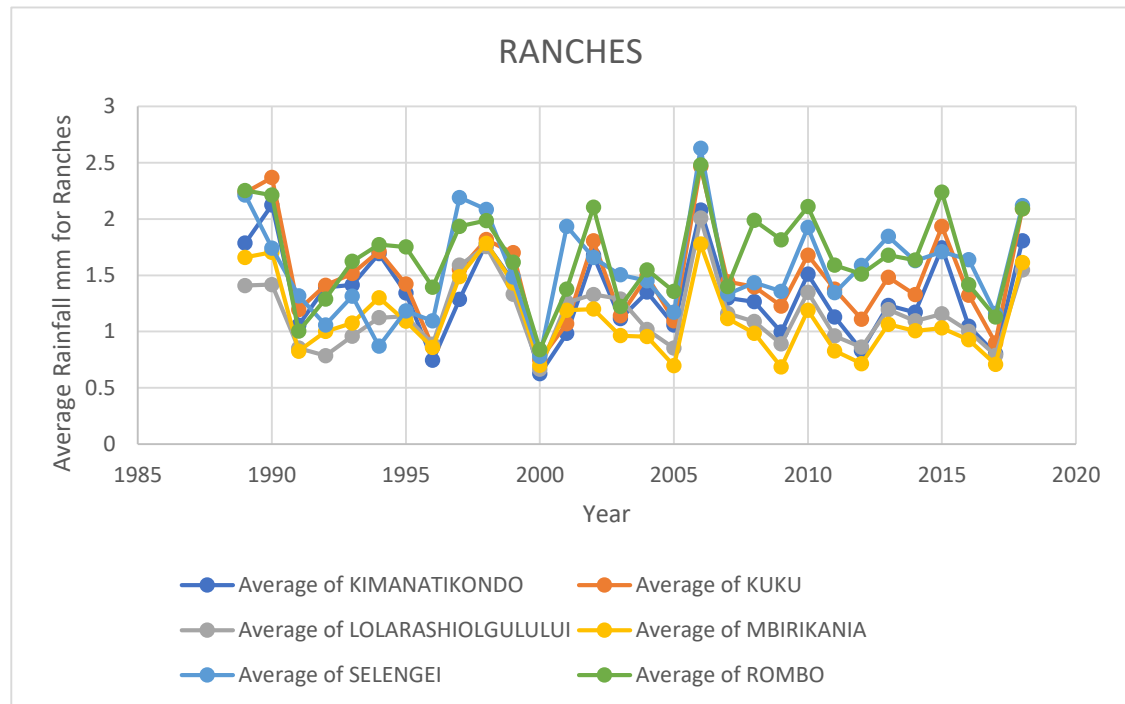


Figure 4.4 Annual precipitation trend for the period of 1988 - 2018

Source, Author (2022)

4.6 The Mann–Kendall Test for Rainfall Trend (MK),

The Mann-Kendall (MK) statistic, a non-parametric test, was employed for trend analysis. It was primarily utilized to assess the pattern of precipitation and temperature over a thirty-year timeframe. The test was initially employed by Mann in 1945 and subsequently by Kendall in 1975. Henceforth, the test has been employed by other researchers for similar investigations like the present one. The World Meteorological Organization (WMO) suggests utilizing the Mann-Kendall test to evaluate trends in time series of environmental data, as demonstrated by Rustum et al. (2017.) This test is considered appropriate for

cases characterized by a presumed monotonic trend. The Mann-Kendall test was used for this study because of its benefits in directly analyzing climate data across specific time periods, such as months, seasons, years, and decades. More precisely, referring to the time span from 1988 to 2018. Furthermore, it did not need a Gaussian distribution of data, rendering it very adaptable.

This study employed the Mann-Kendall test to ascertain if a time series in the study area over a span of three decades had a consistent increasing or declining trend. The null hypothesis posited the absence of any discernible trend. The alternative hypothesis posited a statistically significant trend in the two-sided test or a unidirectional trend (either upward or downward) in the one-sided test.

Table 4.7 Mann-Kendal Test for Trend of Monthly Data

Months	Kendall's tau	p-value	Sen's slope
January	-0.034	0.803	-0.004
February	-0.113	0.392	-0.017
March	0.076	0.568	0.011
April	0.131	0.318	0.026
May	-0.080	0.544	-0.008
June	0.366	0.005	0.006
July	0.228	0.080	0.002
August	0.278	0.032	0.004
September	0.393	0.002	0.006
October	-0.044	0.748	-0.002
November	-0.048	0.721	-0.005
December	-0.218	0.094	-0.054

Source: Author (2022)

The Mann-Kendall (MK) and Sen's slope estimate methods were utilized at a monthly basis to identify patterns in the yearly rainfall series within the Amboseli Ecosystem. The trend was determined using the least significant level α , at which the trend was deemed statistically significant with α confidence level. Table 4.6 clearly demonstrates that the yearly precipitation exhibits a statistically insignificant declining trend at a 95% confidence level ($\alpha = 0.05$). However, notable divergence was seen during the arid months of June, August, and September.

4.7 Temperature Trend

4.7.1 Maximum Temperature

An initial data analysis was conducted to determine the statistical characteristics (mean, standard deviation, range, skewness, kurtosis, and coefficient of variation) of the yearly maximum temperature series from 1988 to 2018. The highest temperature in the region ranged from 33.21°C in March to 25.783°C in January. The average annual maximum temperature is 29.867°C, with a standard deviation of 1.0010. The average value of 1.107 indicates that the annual maximum temperature in the region is asymmetric, with a skewness to the left of the mean, meaning it is left-skewed. The monthly coefficient of variation (CV) for rainfall varied from 4% to 4.1% on average. The coefficient of variation reached its peak in January and reached its lowest point in September. The kurtosis of all data series ranges from 1.107 to -1.017. During the months of January, February, April, August, September, October, November, and December, there was a negative kurtosis, indicating a flat distribution. In the other months, there was a positive kurtosis, indicating a peaked distribution. The statistics parameters for both yearly and seasonal basis are presented below.

Table 4.8 Annual Temperature

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
No. of observations	30	30	30	30	30	30	30	30	30	30	30	30
Minimum	25.783	27.887	27.169	26.676	25.219	24.618	23.724	23.344	26.032	27.889	26.626	25.796
Maximum	30.739	31.475	33.221	29.798	29.018	27.571	26.803	26.021	27.875	30.674	29.843	29.138
1st Quartile	27.736	29.238	29.433	27.283	26.849	25.471	24.120	24.460	26.725	28.777	27.773	27.054
Median	28.895	29.898	29.844	28.125	27.541	25.862	24.847	24.943	27.118	29.194	28.515	27.571
3rd Quartile	29.583	30.670	30.596	28.927	27.930	26.257	25.169	25.335	27.666	29.715	28.983	28.276
Mean	28.645	29.902	29.867	28.115	27.437	25.895	24.770	24.846	27.126	29.212	28.348	27.670
Variance (n-1)	1.432	1.003	1.483	0.834	0.757	0.476	0.493	0.495	0.303	0.586	0.647	0.862
Standard deviation (n-1)	1.197	1.001	1.218	0.913	0.870	0.690	0.702	0.704	0.550	0.766	0.804	0.928
Variation coefficient (n)	0.041	0.033	0.040	0.032	0.031	0.026	0.028	0.028	0.020	0.026	0.028	0.033
Kurtosis (Pearson)	-0.478	-0.868	1.107	-1.106	0.047	0.068	0.441	-0.092	-1.017	-0.578	-0.637	-0.704
Standard error(Kurtosis (Fisher))	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833

Source: Author (2022)

The outcomes of the Mann-Kendall Test conducted on the monthly maximum temperature from 1988 to 2018 are presented in Table 4.8. The Table indicates that the yearly mean temperature exhibits a statistically significant positive trend at a 5% significance level. The monthly temperature exhibited a notable upward trend, especially during April, June, July, and August. However, there was no statistically significant increase in the remaining months, with a confidence level of 95%.

Table 4.9 Annual Temperature

Months	Kendall's tau	p-value	Sen's slope
January	0.352	0.007	0.074
February	0.214	0.101	0.044
March	0.232	0.074	0.051
April	0.264	0.042	0.043
May	0.402	0.002	0.050
June	0.416	0.001	0.049
July	0.393	0.002	0.040
August	0.545	<0.0001	0.054
September	0.352	0.007	0.030
October	0.320	0.014	0.050
November	0.476	0.000	0.057
December	0.476	0.000	0.061
Average	0.660	<0.0001	0.050

Source: Author (2022)

The statistical parameters, including mean, standard deviation, range, skewness, kurtosis, and coefficient of variation, were calculated for the annual minimum

temperature data spanning from 1988 to 2018. As per Table 4.8, the minimum temperature in the region ranged from 19.44°C in February to 12.95°C in September. The mean annual minimum temperature was 14.70°C, with a standard deviation of 0.49°C. The skewness of the average value, which is -0.434, suggests that the distribution of the annual lowest temperature in the region is asymmetric and skewed to the left. The monthly temperature coefficient of variation (CV) ranged from 4.70% to 14.08% on average, with the maximum CV occurring in December and the minimum in April. The kurtosis values for all the data series ranged from -0.80 to 5.182. In the months of July, August, September, October, and November, the data were concentrated, indicated by positive kurtosis values. In contrast, all other months exhibited negative kurtosis, signifying a more evenly dispersed distribution.

Table 4.10 Decadal Temperature Pattern

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
No. of observations	30	30	30	30	30	30	30	30	30	30	30	30
Minimum	25.783	27.887	27.169	26.676	25.219	24.618	23.724	23.344	26.032	27.889	26.626	25.796
Maximum	30.739	31.475	33.221	29.798	29.018	27.571	26.803	26.021	27.875	30.674	29.843	29.138
1st Quartile	27.736	29.238	29.433	27.283	26.849	25.471	24.120	24.460	26.725	28.777	27.773	27.054
Median	28.895	29.898	29.844	28.125	27.541	25.862	24.847	24.943	27.118	29.194	28.515	27.571
3rd Quartile	29.583	30.670	30.596	28.927	27.930	26.257	25.169	25.335	27.666	29.715	28.983	28.276
Mean	28.645	29.902	29.867	28.115	27.437	25.895	24.770	24.846	27.126	29.212	28.348	27.670
Variance (n-1)	1.432	1.003	1.483	0.834	0.757	0.476	0.493	0.495	0.303	0.586	0.647	0.862
Standard deviation (n-1)	1.197	1.001	1.218	0.913	0.870	0.690	0.702	0.704	0.550	0.766	0.804	0.928
Variation coefficient (n)	0.041	0.033	0.040	0.032	0.031	0.026	0.028	0.028	0.020	0.026	0.028	0.033
Kurtosis (Pearson)	-0.478	-0.868	1.107	-1.106	0.047	0.068	0.441	-0.092	-1.017	-0.578	-0.637	-0.704
Standard error (Kurtosis Fisher)	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833

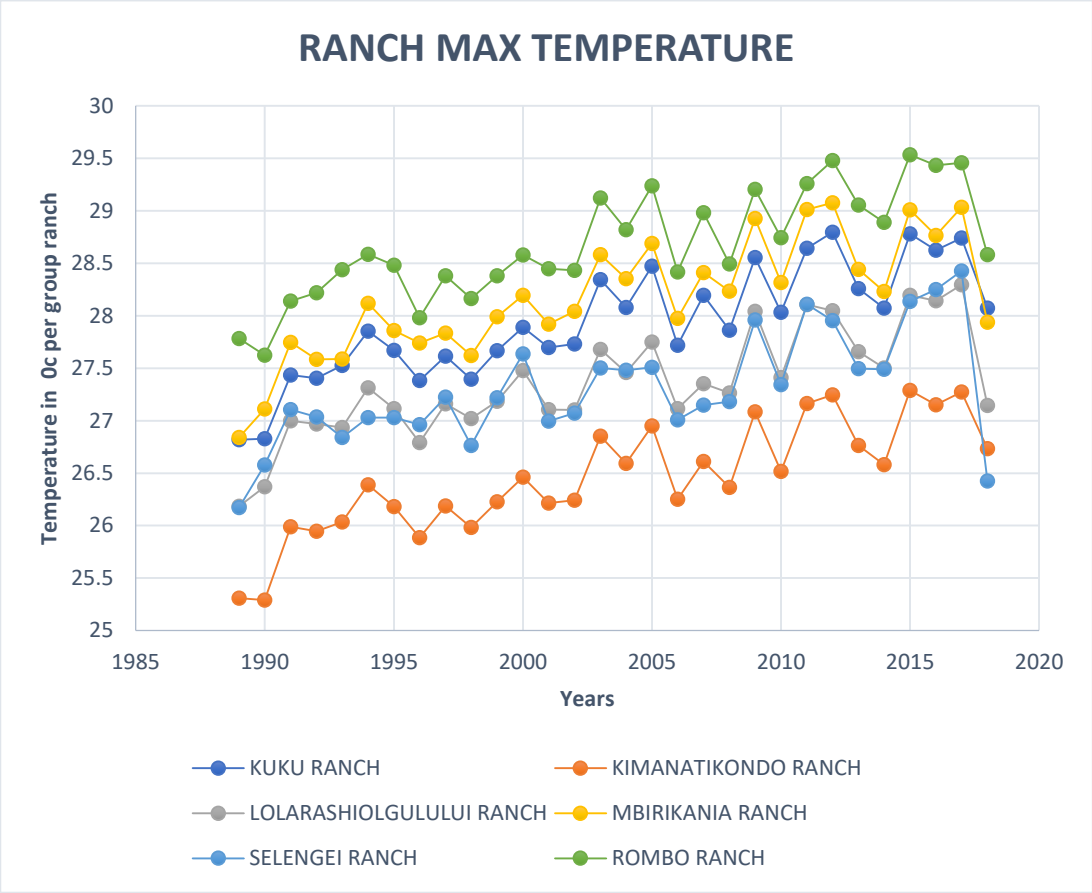


Figure 4.5 Trend in Maximum Temp

Temperature in the Group Ranches for the Period of 1988-2018

The average highest temperature in the six group ranches exhibited an upward trend (Fig.4.5). Nevertheless, the Rombo Ranch recorded the greatest average temperature over 27oC, while the Kimana-Tikondo Ranch documented the lowest temperature below 25oC. The maximum average temperature at all the other ranches ranged from 26°C to 29°C. The impact of increasing temperature is expected to be most pronounced in group farms that have previously been subjected to somewhat cooler temperatures. Over the course of 30 years, the lowest annual temperature in the Amboseli Ecosystem increased from 16oC in the 1990s to 17.2oC in 2017. However, there was a considerable decrease to 16oC in 2018 (Fig. 4.6). The decrease in the lowest temperature in 2018 was ascribed to a prolonged duration of cloud cover throughout the year.

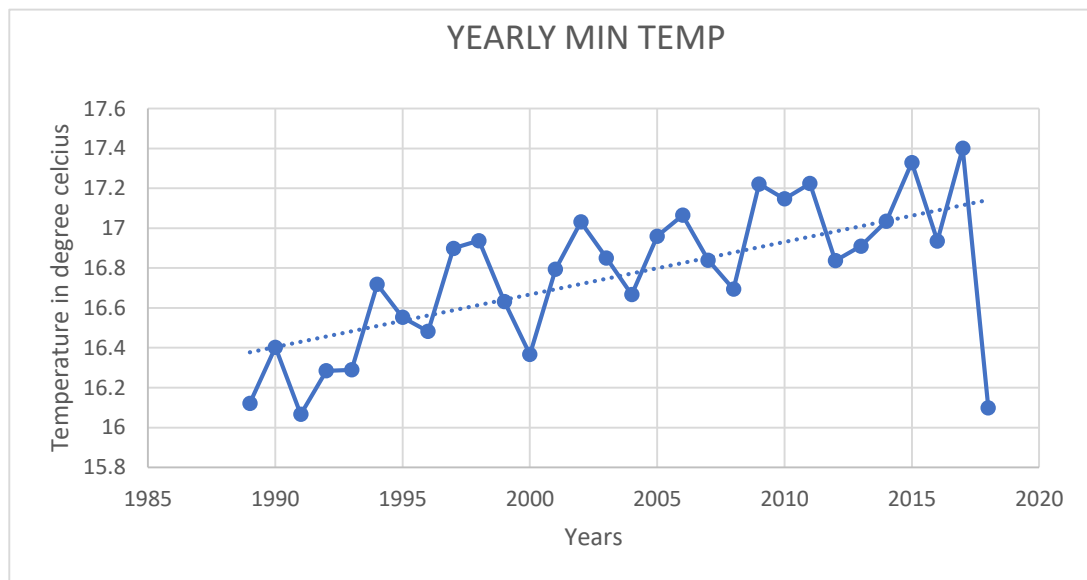


Figure 4.6 Temperature Trend in Annual Minimum Temperature for the Period of 1989-2018

The lowest temperature data underwent a Mann-Kendall test to determine the significance of their trend. The findings shown in Table 4.10 indicate that there was

a notable degree of variance in the average minimum temperature throughout the months of January, March, and April, as well as during the months spanning from August to November. There was no notable fluctuation in the lowest temperature inside the research region for the remaining months.

Table 4.11 Mann-Kendal Test for Minimum Temperature

Series\Test	Kendall's tau	p-value	Sen's slope
MIN TEMP			
JAN	0.292	0.025	0.025
FEB	0.209	0.108	0.027
MAR	0.301	0.020	0.026
APR	0.439	0.001	0.034
MAY	0.140	0.284	0.009
JUN	0.260	0.046	0.029
JUL	0.264	0.042	0.019
AUG	0.333	0.010	0.034
SEP	0.310	0.017	0.022
OCT	0.370	0.004	0.048
NOV	0.467	0.000	0.036
DEC	0.228	0.080	0.020

Table 4.11 presents the outcomes of the Mann-Kendall test for the monthly minimum temperatures spanning from 1988 to 2018. The table indicates a slight upward trend in the annual average minimum temperature, but this shift was not statistically significant. Throughout the study period, there was a general increasing pattern, but, as in previous months, noticeable upward trends were observed in

January, March, April, and July. However, these rising trends were negligible at the 5% significance level over the study duration.

4.8 Effects of Climate Variability on Pasture and Water Resources

4.8.1 Analysis of Satellite Images

A visual comparison was conducted for post-classification by analyzing satellite imagery. The figures 4.7, 4.8, and 4.9 represent classifications for various topics obtained from Landsat images spanning three decades. Figure 4.7 represents the time period from 1988 to 1998. Figure 4.8 represents the time period from 1998 to 2008. Figure 4.9 represents the time period from 2008 to 2018. According to Figure 4.7a, the research area had 65.7% abundant green vegetation in 1998, indicating that the land was undisturbed and had enough pasture for cattle. Rangeland and open grasslands accounted for 10.1% of the total area, while shrub land with open regions of tall grass occupied 16.1%. Water sources constituted 1% of the total area, while barren ground represented 7.1%. The middle part of Amboseli National Park had the largest portion of the open water.

Figure 4.8 illustrates the supervised classification, showing a significant decrease of over 96% in thick vegetation by the year 2008. The area of barren terrain increased by 12%, whilst the area of shrub land fell by 13%. The supervised classification findings indicate a decline in the extent of densely vegetated areas by the year 2018, as shown in Figure 4.9. this could be attributed to increase in rangelands as a result of less rainfall or due to population growth that may have increased settlement. The area occupied by rangelands had a substantial expansion which could as well be attributed to human interference or overgrazing in times of pasture scarcity, whereas other plant

kinds exhibited a noticeable decline. The land cover had undergone alterations as a result of soil deterioration and its conversion for agricultural and settlement purposes.

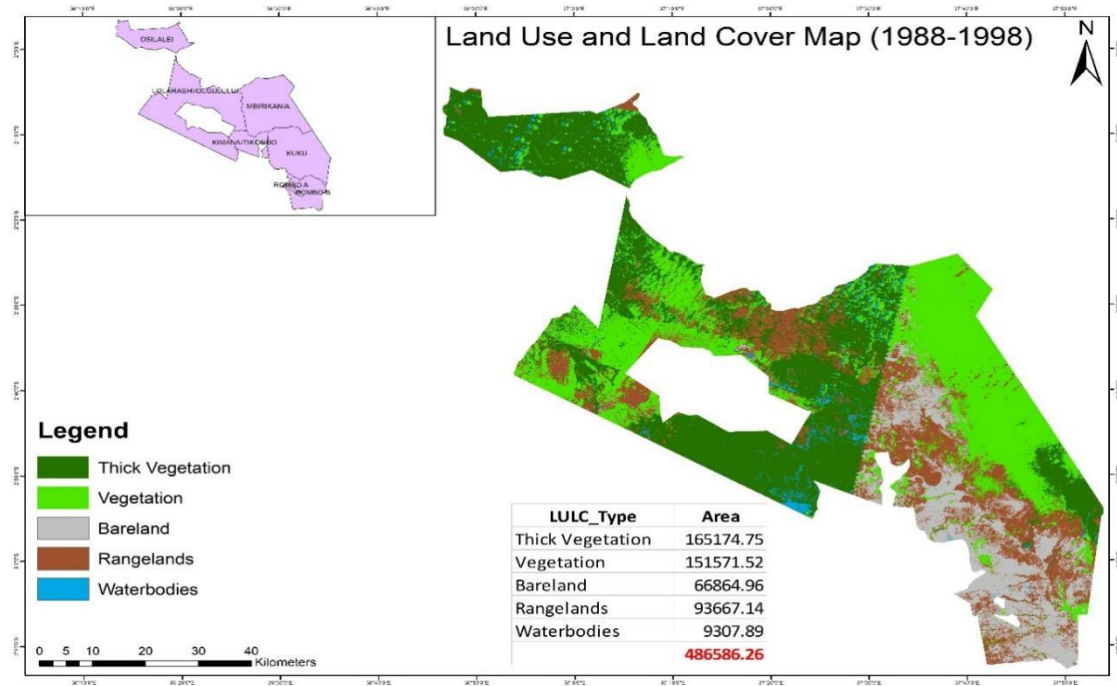


Figure 4.7 Land Cover Map (1988-1998)

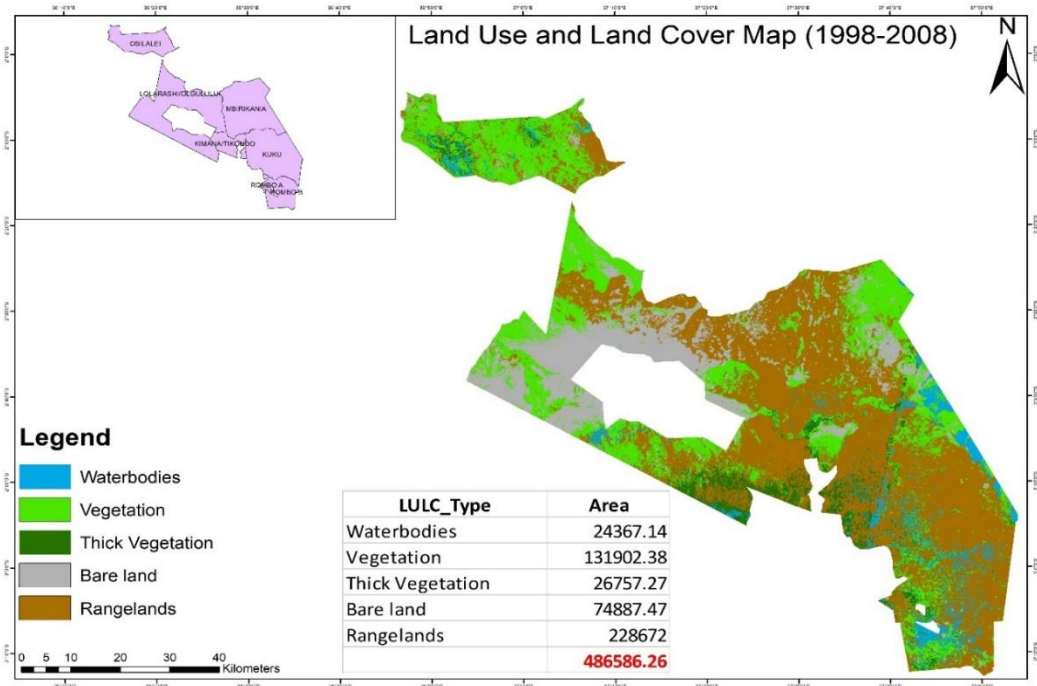


Figure 4.8 Land Cover Map (1998-2008)

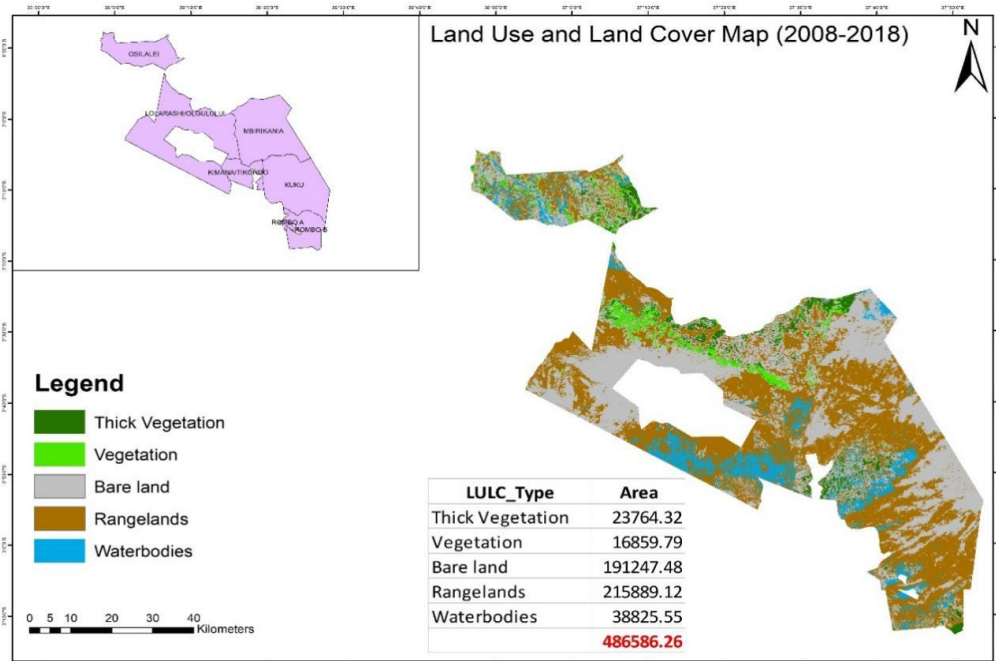


Figure 4.9 Land Cover Map (2008-2018)

Upon analyzing the three maps, it becomes apparent that there has been a progressive alteration in the physical characteristics of the area over the course of three decades.

This suggests that there has been a significant alteration in the land cover of the area throughout time, particularly an expansion of range land. This change can perhaps be related to shifts in the climate.

The supervised classification revealed that Figure (a) shows a significant concentration of vegetation (indicated by dense green color) during the period from 1988 to 1998. In contrast, Figures b and c demonstrate a decline in vegetation, including the same and other types, during the periods 1998-2008 and 2008-2018, respectively. During the period from 2008 to 2018, there was a notable expansion of rangelands and a significant decrease in the extent of natural plant cover. This suggests a decrease in rainfall and a potential rise in human activities as a response to climate change, similar to the period from 1998 to 2008 (Figure b). There was a notable decrease in the extent of area covered by dense vegetation during the course of three decades. Therefore, these data suggest that there is a significant decrease in vegetation and other types of land cover as a result of an expansion of rangelands, which has led to a notable rise in bare land.

4.8.2 Post Classification Area Comparison

An analysis was conducted to compare the areas of different posts. The vegetation cover for the periods 1988-1998, 1998-2008, and 2008-2018 was analyzed and the findings are provided in Table 7.4.1. The findings revealed the existence of dense vegetation from 1988 to 1998, accounting for 33.95% of the total categories. The proportion of other vegetation was roughly 31.15%. Rangelands and barren ground accounted for 19.25% and 14.74% of the total area, respectively. In 2008, there was a decrease in plant cover across the research region, particularly in the Olgulului-Ololarashi and Eselenkei group ranches, where cattle numbers remained high. The

thick vegetation cover was measured at 5.5%. The vegetation over the same period decreased by 4.04% from the class coverage in 1998, resulting in a vegetation coverage of 27.11%. During the same time frame, there was a 27.75% expansion of rangelands compared to the class coverage in 1998.

The percentage of bare land increased from 13.74% in 1999 to 15.39% in 2009. In 2018, there was a marginal decrease of 0.62% in dense vegetation compared to the coverage of the same class in 2008. During this same time period, there was an additional decrease in the amount of other vegetation, which went from 27.11% in 2008 to 3.46%. In addition, there was a decrease in rangelands by 2.62% between 2008 and 2018. The percentage of bare land had a significant rise from 15.3% in 2008 to 39.3% in 2018. Within a period of thirty years (1988-2018), there was a significant decrease of 29.07% in the extent of dense vegetation cover. There was a 27.69% decrease in other forms of plant life. In other areas, the use of rangelands grew by 25.13%, while the amount of barren land increased by 25.56%. This suggests that the expansion of rangelands may be due to climatic fluctuations and the clearing of land for commercial purposes, with the aim of reducing vulnerability

4.8.3 Magnitude and Trend of Change in Land Cover

Analyzed visual photographs to assess the extent and pattern of changes in plant cover over a span of three decades. The objective was to delineate the extent of dense foliage, various types of plant cover, grazing fields, and barren terrain. The results were displayed in Table 4.4, which may be found in Appendix XI.

According to tables 4.7, 4.8, and 4.9, the findings showed that throughout the periods (1988-1998), (1998-2008), and (2008-2018), the area covered by dense vegetation decreased by 138417.48 hectares (28.45%), whereas the area covered by other vegetation

decreased by 19669.14 hectares (4.04%). The area of rangelands expanded by 135004.86 hectares, representing a growth of 27.75%. Additionally, the area of bare land rose by 8022.51 hectares, equivalent to 1.65%. From 1998 to 2008, there was a decrease of 2992.95 hectares (0.62%) in dense vegetation cover, and a decrease of 11502.59 hectares (23.65%) in other vegetation cover from 2008 to 2018. The area of rangelands decreased by 12,782.88 hectares, representing a reduction of 2.62%. In contrast, the area of bare land cover expanded by 116,360.01 hectares, which corresponds to a growth of 23.91%. The data illustrate the gradual expansion of rangeland usage over time, leading to a decrease in plant cover and an increase in dense shrub cover in the studied region. The findings also suggest that the utilization of rangeland has led to the growth of bare land cover, mostly owing to an increase in cattle population that exceeded the carrying capacity of the study region, resulting in a loss in available vegetation.

A direct correlation between water availability and milk output was found. This is due to the increased availability of water, which in turn made pasture more accessible for animals to consume thus an increase in milk productivity. According to the study, 84.5% of the participants agreed, while 14.1% reported no observed difference. 1.4% of the participants held the belief that the decrease in milk production was caused by the limited availability of water sources, which might perhaps be indirectly linked to the availability of pasture.

Regarding the relationship between water availability and herd size, it is noteworthy that the majority of respondents (78.5%) believed that herd size tends to rise with the presence of more water sources. The percentage of individuals who had an opposing viewpoint was 3%. 21.3% of the participants had the belief that there was no alteration. Pastoralists may feel more inclined to increase their cattle holdings when water supplies are close and reliable, as opposed to when these sources are far and scarce.

4.8.4 Accuracy Assessment

The research region underwent accuracy testing over a span of three decades, specifically from 1988 to 1998, 1998 to 2008, and 2000 to 2018. As stated by OLM (2014), accuracy assessment played a crucial role in determining the reliability of information derived from remotely sensed data. It involved comparing the classified image with a trusted or ground truth data source, making it an essential step in any classification. Esri (2021). Additionally as suggested by Rwanga and Ndambuki (2017) the estimation was done and presented in Table 4.12 below

Table 4.12 Accuracy Assessment Matrix

	Water body	Thick vegetation	Open shrub land with tall grass	Rangeland	Bare land	Total (user)
Water Body	3	3	3	0	0	9
Thick vegetation	0	3	1	0	0	4
Vegetation	0	0	26	0	0	26
Rangelands	0	0	0	21	0	21
Bare land	0	0	2	1	11	14
Total (producer)	3	6	32	22	11	74

Overall accuracy = $\frac{\text{Total number of correctly classified pixels (diagonal)}}{\text{Total number of reference pixels}} \times 100$

Total number of reference pixels

$$= 64/74 * 100 = 86.49\%$$

User accuracy calculation (commission)

Water bodies = $3/9 \times 100 = 33.33\%$

Thick vegetation = $3/4 \times 100 = 75\%$

$$\text{Vegetation} = 26/26 \times 100 = 100\%$$

$$\text{Rangelands} = 21/21 \times 100 = 100\%$$

$$\text{Bare land} = 11/14 \times 100 = 78.57\%$$

Producer accuracy calculation (omission)

$$\text{Water bodies} = 3/3 \times 100 = 100\%$$

$$\text{Thick vegetation} = 3/6 \times 100 = 50\%$$

$$\text{Vegetation} = 26/32 \times 100 = 81.25\%$$

$$\text{Rangelands} = 21/22 \times 100 = 95.45\%$$

$$\text{Bare land} = 11/11 \times 100 = 100\%$$

Kappa Coefficient

$$\text{Kappa Coefficient (T)} = \frac{(TS \times TCS) - \sum(\text{Column Total} \times \text{Row Total})}{TS^2 - \sum(\text{Column Total} \times \text{Row Total})} \times 100$$

Where;

TS= Total Sample = 74

TCS= Total Correctly Classified Sample = 64

So,

$$\text{Kappa Coefficient (T)} = \frac{(74 \times 64) - \sum((3 \times 9) + (6 \times 4) + (32 \times 26) + (22 \times 21) + (11 \times 14))}{5476 - \sum((3 \times 9) + (6 \times 4) + (32 \times 26) + (22 \times 21) + (11 \times 14))} \times 100$$

$$\text{Kappa Coefficient (T)} = \frac{4739 - 1499}{5479 - 1499} \times 100$$

T = 81.41% (0.8141)

Table 4.11 indicated that that the level of error of commission against omission for thick vegetation cover was 75% and 50% respectively. Other forms of vegetation was 100% and 81.25% respectively. Rangelands was 100% and 95.45% respectively whereas bare land cover was 78.57% and 100% respectively. In this research there was confirmation of the overall accuracy score of 86.49% reflects a high level of accuracy, and a Kappa coefficient of 0.814 was also obtained elsewhere. This suggests that the maps exhibit a substantial degree of precision. presented were accepted thus making them suitable in making deduction on the level of vegetation cover and by extension the adaptation strategies put in place within the study area for a period of three decades.

Classification 2008-2018

Table 4.13 Accuracy Assessment matrix

	Water body	Thick vegetation	Vegetation	Rangelands	Bare land	Total (User)
Water body	3	0	1	1	0	5
Thick vegetation	0	2	1	0	0	3
Vegetation	0	0	20	0	2	22
Rangelands	0	0	1	23	0	24
Bare land	0	0	0	2	18	20
Total (producer)	3	2	23	26	20	74

Overall accuracy = $\frac{\text{Total number of correctly classified pixels (diagonal)}}{100}$

100

Total number of reference pixels

$$= 66/74 \times 100$$

$$= 89.19 \text{ in percentage of correctly classified pixels}$$

User Accuracy Calculation (Commission)

Water bodies = $3/5 \times 100 = 60\%$

Thick vegetation = $2/3 \times 100 = 66.67\%$

Vegetation = $20/22 \times 100 = 90.91\%$

Rangelands = $23/24 \times 100 = 95.83\%$

Bare land = $18/20 \times 100 = 90\%$

Producer accuracy calculation (omission)

Water bodies = $3/3 \times 100 = 100\%$

Thick vegetation = $2/2 \times 100 = 100\%$

Vegetation = $20/23 \times 100 = 86.96\%$

Rangelands = $23/24 \times 100 = 95.83\%$

Bare land = $18/20 \times 100 = 90\%$

Kappa Coefficient

Kappa *Coefficient* (*T*) =

$$\frac{(TS \times TCS) - \sum(\text{Column Total} \times \text{Row Total})}{TS^2 - \sum(\text{Column Total} \times \text{Row Total})} \times 100$$

Where;

TS= Total Sample = 74

TCS= Total Correctly Classified Sample = 66

Therefore the Koppa Coefficient was as follows

Kappa Coefficient (T)=

$$\frac{(74 \times 66) - \sum ((3 \times 5) + (2 \times 3) + (23 \times 22) + (26 \times 24) + (20 \times 20))}{5476 - \sum ((3 \times 5) + (2 \times 3) + (23 \times 22) + (26 \times 24) + (20 \times 20))} \times 100$$

$$T = \frac{4884 - 927}{5476 - 927} \times 100$$

$$T = 86.99\% (0.8699)$$

The results as presented in the table above showed that the errors of commission and omission that occurred during interpretation of data was the presence of the thick vegetation cover by 66.67% and 100% respectively. On the other hand, other forms of vegetation cover were 90.91% and 86.96% respectively. Besides that, rangelands cover had 95.83% and 95.83% respectively. Land cover were 90% and 90% respectively. By interpretation, the results presented were accurate and a true reflection on what was practically happening on the ground examining the level of vegetation use and land uses options inform of adaptation strategies such as crop growing or small business enterprises across the area of study, Overall accuracy for the six group ranches was 89.19% and Kappa coefficient value of 0.8699. Both of these results were good indications of substantial reliability and validity

4.9 Households' Vulnerability to Climate Variability

4.9.1 Sources of Income for Households

Other sources of income apart from livestock rearing were investigated by the study. This was to find out if such sources inform of adaptation strategies were actually reducing vulnerability at the household level. The responds gave the following as summarized in table 4.14. The results showed that 85.6% of the households had alternative sources of income and only 14% of the responds indicated that they relied on their livestock only for family income.

Table 4.14 Alternative sources of household income (Yes- those who had alternative sources and No signified those without)

	Frequency		Percent
YES	310		85.6
NO	52		14.4
Total	362		100.0

Source Survey Data (2022)

4.9.2 Household Vulnerability

This study utilized an integrated vulnerability strategy to create vulnerability indices for every family in Amboseli Ecosystem. The identical methodology was employed as advised by Madu (2018) and Tesso et al., (2018). This research made the assumption that families with more adaptive ability are less vulnerable to the effects of climate-induced pressures, thereby maintaining a consistent level of exposure.

The findings indicated that 70.2% of households in Kajiado experienced a notable rise in temperature fluctuations throughout the period of 1988-2018. 75.4.1% of the homes observed a reduction in rainfall, while 74.3% observed a consistent rise in

drought conditions. 73.2% reported a reduction in floods, whereas 82.9% indicated a rise in animal illnesses.

From 1988 to 2018, a majority of 72.7% reported a decline in the accessibility of water for both livestock and household purposes. The incidence of border disputes had a 77.3% rise. The area had numerous drought occurrences, which had severe repercussions on the lives of households. In periods of drought, there was a decline in both the supply of pasture and water. Reports indicate that there has been a rise in both food insecurity and malnutrition among children under the age of five during periods of drought.

Inter-community ethnic strife, such as that between the Maasai and Kamba to the East, mostly arose from the escalating scarcity of grazing land and water supplies. Conversely, there were reports of inter-ethnic clashes between the Kenyan and Tanzanian Maasai pastoralists living in close proximity to the border. These disputes led to the loss and theft of livestock.

Additionally, it was shown that there were frequent occurrences of significant damage to both property and means of subsistence. Conversely, drought hindered the movement of both people and cattle populations, as well as impeding development endeavors. The aforementioned data indicate that Pastoralism, as a means of subsistence, is intricately linked to environmental services, including intricate systems of social, political, and economic structure. Furthermore, the Convention on Biological Diversity (2010) and Western et al., (2020) assert that pastoralists inhabit arid and semi-arid regions (ASALs), where their way of life and cultural practices revolve upon large cattle rearing.

The statement is substantiated by the results of focus group discussions conducted in the research region, which verified that the drought's consequences compelled individuals to travel significant distances in search of water and grazing land. As a result, this occasionally led to school-age children being absent from school or even permanently leaving school in certain cases. Furthermore, the respondents emphasized that human-wildlife conflict was a significant worry since they experienced cattle losses during interactions with wild predators. During the FGD at Kimana, a participant highlighted a significant livestock loss in 2009. This loss was attributed to the competition for pasture and water resources between domestic animals and wild animals. The economic impact of this event was severe, affecting numerous families, some of whom are still struggling to recover from the resulting hardships.

An intriguing point raised during the same FGD was that families whose members were gainfully employed due to their education were able to rebound from the 2009 drought. This is mostly due to their ability to buy essential necessities and simultaneously replenish their livestock following the conclusion of the drought period. The FGD's report on this drought experience highlighted the necessity of formal education.

4.9.3 Socio-Economic and Bio-Physical Vulnerability

Education had a crucial role in facilitating the youth's access to career opportunities. The results of this survey, as shown in Table 4.2 in the appendix, revealed that over 86% of the participants had received basic or elementary education, while the remaining individuals were illiterate. Lack of literacy diminishes a household's capacity to comprehend climate information and

engage in diverse economic activities. The data on household size revealed that 66% of the individuals surveyed had a household size above five people, with 50.7% of the respondents stating that they had more than five dependents.

The gender of the household head is crucial for climate change adaptation. The survey revealed that 59% of the families were led by males, whereas 41% were led by females (Table 4.2). Male family heads had greater levels of education in comparison to female household heads. The findings suggested that homes led by women were more susceptible to climate-related pressures compared to households led by males. This is mostly due to the limited participation of women in community-level decision-making processes, particularly in areas related to pasture and water management. Furthermore, males seized any possible chance for alternate means of earning a living, while women stayed at home to attend to childcare responsibilities and do household tasks.

The study revealed that the vulnerability of families is impacted by several factors, including the gender and education level of the household head, as well as the size of the family, particularly the number of dependent children. As the number of dependents increases, so does the amount of vulnerability.

Households should use revenue source diversity as an adaptive technique. The survey revealed that over 55.5% of households lacked additional sources of income and relied primarily on livestock as their primary source of earnings. Moreover, the survey results indicated that a small number of households engaged in both crop cultivation and animal rearing.

This study discovered that a significant majority of homes examined, specifically 78%, did not have any of their family members involved in formal work. A

majority of the participants (82.1%) in the group ranches were found to employ more than two adaptation techniques as a means of managing and enhancing their livelihood in an environment that is undergoing fast change. The high unemployment rate among young people poses a significant challenge, highlighting the need for alternative livelihood options, particularly those that are environmentally focused. Examples of such options include beekeeping, establishing tree nurseries, setting up curio shops in strategic locations near Amboseli National Park, and engaging in bead making to cater to both local and international tourists.

The vulnerability of a household to climatic fluctuation is determined by environmental, economic, and biophysical variables. The findings of this study, as presented in Table 4.14, demonstrate that a significant proportion (86.7%) of households experienced sensitivity and exposure to climatic variability. Bobadoye et al. (2017) conducted a literature review which indicated that in order to effectively adapt to climate-related pressures, it is crucial to focus on household-level interventions. This is because the impacts of climatic variability and change are most strongly experienced at this level. Within the Amboseli Ecosystem, families experienced many significant hazards over the previous three decades, resulting in an elevated level of vulnerability.

A precise understanding of weather patterns and their potential effects on lifestyles was crucial for pastoralism as a means of production. Throughout this study, around 58% of the participants saw a rise in temperature and a decline in rainfall using conventional indicators while residing in the Amboseli Ecosystem. It was observed that this had an impact on their socioeconomic level as well as

the purchasing power of the community.

The understanding of changes in crucial climatic factors by indigenous communities is significant, since it heightens the vulnerability of households to climate-related pressures, as stated in Ombogo's study in 2013.

The factors used to assess the vulnerability of households were classified into three categories: social, economic, and environmental characteristics. Prior to doing the factor analysis (PCA), the data for each of the hypothesized variables underwent the Kaiser-Meyer-Olkin (KMO) Test. The purpose of the test was to assess the suitability of the data for conducting a factor analysis and to determine the availability and validity of the desired measurements. The calculated statistic was an index measure that ranged from 0 to 1. The interpretation of the data was quite straightforward, as a number closer to 1 indicated a better outcome compared to a value closer to zero.

Table 4. 15 KMO and Bartlett's Test

KMO and Bartlett's Test

Kaiser-Meyer-Olkin measure of sampling adequacy		.597
Bartlett's test of Sphericity	Approx. Chi-Square	685.855
	df	171
	Sig.	.000

Greenacre et al.,(2022) said that factor analysis maybe conducted if the Kaiser-Meyer-Olkin (KMO) value above 0.5 and the Bartlett's test result was below 0.1.The KMO measure of sample adequacy was observed to be 0.597, suggesting

that the model was quite good (Table 4.14). After verifying the suitability of the data for PCA, the vulnerability indicators that were found were subjected to analysis. A principal component analysis was performed on fourteen (14) indicator variables predicted to contribute to household vulnerability, including social, economic, and environmental aspects. The resulting impact scores are presented in Table 4.15. The analysis of social vulnerability factors revealed that the gender of the household head, degree of education, duration of residency, and the person responsible for livestock care had a beneficial impact on the vulnerability of households to climatic variability. Household sensitivity to climatic variability was negatively impacted by the age of the household head and the size of the family. The good traits enhanced resilience, but the negative attributes diminished it. The primary factors influencing household vulnerability were the degree of education, with a prevalence of 86%, and the gender of the household head, accounting for 59%. Additionally, family size had a significant role, contributing 50.7% to household vulnerability. Regarding the economic vulnerability variables, four factors were shown to positively impact household vulnerability, whereas two components had a negative impact. The size of the family's herd, the makeup of the herd, and the tactics used to adapt had a beneficial impact on the household's vulnerability at the household level. The formal employment of family members has a beneficial impact on lowering household vulnerability. Families that had bigger cattle herds and engaged in an extra income-generating activity exhibited superior resilience to climate shocks and pressures, in contrast to those that relied primarily on pastoralism. Households that had no alternative source of income and less livestock diversity had limited capacity for resilience against adverse climatic

variation. Table 4.16 displays the vulnerability level based on social, economic, and environmental parameters. The results above were obtained from the respondent's survey data.

Table 4.16 Social, Economic and Environmental Indicators and Their Effect on Vulnerability Level

Hypothesized variables	Percentage	Influence on vulnerability
<i>Social vulnerability variables</i>		
Gender of the respondent-HH: Male-headed	59.1	+
Age of the respondent HH head: 50+ years	36.2	-
Level of education of the respondent	86.2	+
HH size: more than 9 persons	50.7	-
Experiences in the area: less than 5 years	34.1	+
Person responsible to take care of animals: Both	23.5	+
<i>Economic vulnerability variable</i>		
Alternative source of income	44.5	-
Herd size: More than 20 livestock	28.3	+
Herd structure: no of cattle	62.8	+
HH employed: no member of HH employed	78.1	+
HH Adaptation strategies: Those with more than 2 adaptation strategies other than pastoralism	82.1	+
Livestock diversity: less than 3 livestock species	45.4	-
<i>Environmental vulnerability variable</i>		
Climate change: experiencing change	86.7	+
Temperature: experiencing increase	57.9	+
Drought: noticed increasing events	6.4	+
Flood: noticed change	7.1	+
Wind: noticed unusual change	12.6	+

Source: Author (2022)

The Data collected from the respondents also indicated that all climate-related factors had a beneficial impact on household vulnerability as indicated by the environmental vulnerability indicators. The primary factor contributing to

household vulnerability was climatic variability, accounting for 86.7% of the effect, followed by a temperature increase of 58%. Additional variables. The vulnerability of households was little affected by factors such as wind, land floods, and the frequency of drought episodes. Although the impacts of individual climate variables may be minor, the combined exposure to all of them might diminish family resilience.

PCA facilitated the representation of multidimensional data by condensing it into a reduced number of variables, known as summary indices, for the purpose of identifying patterns, discontinuities, groupings, and exceptional values. It revealed the connections between observations and variables, as well as the relationships among the variables. The factor scores (weights) from the initial principal component analysis had good correlations with most of the indicators discovered under adaptive ability, exposure, and sensitivity. When exposure and sensitivity are kept equal, a negative index indicates that the household has a comparatively weaker adaptive capacity compared to a home with a positive index value, and vice versa.

Within the Olgulului-Ololarashi group ranch, located adjacent to Amboseli National Park, women were actively involved in the creation of bead crafts as a supplementary means of generating cash. The ladies demonstrated ingenuity and crafted exquisite merchandise and decorations, which they marketed to tourists frequenting Amboseli National Park and the adjacent tourist settlements. In addition, they established social collectives aimed at enhancing the financial capabilities of their members, such as "merry-go-round," "Tuinuane" (a Swahili term denoting mutual upliftment), and various forms of social support organizations. These groups provided economic empowerment to household

members by facilitating their access to financial loans.

The vulnerability index was calculated using indications of adaptive capability, which showed a positive correlation with the first principal component analysis, as well as indicators of sensitivity and exposure, which showed a negative correlation. The variables examined encompassed the gender of the household leader, educational attainment, and possession of livestock. Nevertheless, the research took into account all factors in terms of exposure and sensitivity. Adaptive capability is seen as a beneficial aspect in reducing vulnerability.

Exposure and sensitivity have a detrimental impact on reducing vulnerability. A higher factor score indicates greater significance of the variable and a stronger contribution to the household's vulnerability.

The households were categorized into three groups based on the vulnerability index: Households that were in a vulnerable condition but nevertheless had the ability to manage were relatively less susceptible. Households classified as moderately sensitive need immediate yet temporary aid in the event of climate-induced shocks and pressures. Highly vulnerable homes were on the brink of irreparable circumstances. The examination of these vulnerability categories revealed that 34% of the homes examined in this study were classified as moderately susceptible, indicating the majority. These families had an index ranging from -1.00 to 1.00. The homes with lower vulnerability levels ranged from 1.1 to 3.0 on the vulnerability index and accounted for 29% of the households included in the sample. On the other hand, the households with higher vulnerability levels had an index ranging from -0.9 to -0.3 and formed 27% of the total households sampled, as indicated in Table 4.16.

Female-led families were determined to be more susceptible than households led by males. This may be attributed to the patriarchal character of the Maasai community. Female participation in decision-making within this group is minimal. Widowed women had significant disadvantages since males held the primary authority in determining the options for alternate means of supporting themselves. In some locations, the transfer of property upon death did not occur automatically. Furthermore, land ownership is exclusively held by men, unless in highly exceptional cases. Occasionally, the eldest sons assumed the duty of managing their houses. Relatives of deceased male households had the authority to approve livestock management choices in widowed households. Reduced availability of adaptive methods was observed to correlate with increased household vulnerability. There is a decrease in the number of adaption techniques at the household level. The following is a depiction of vulnerability based on each group ranch.

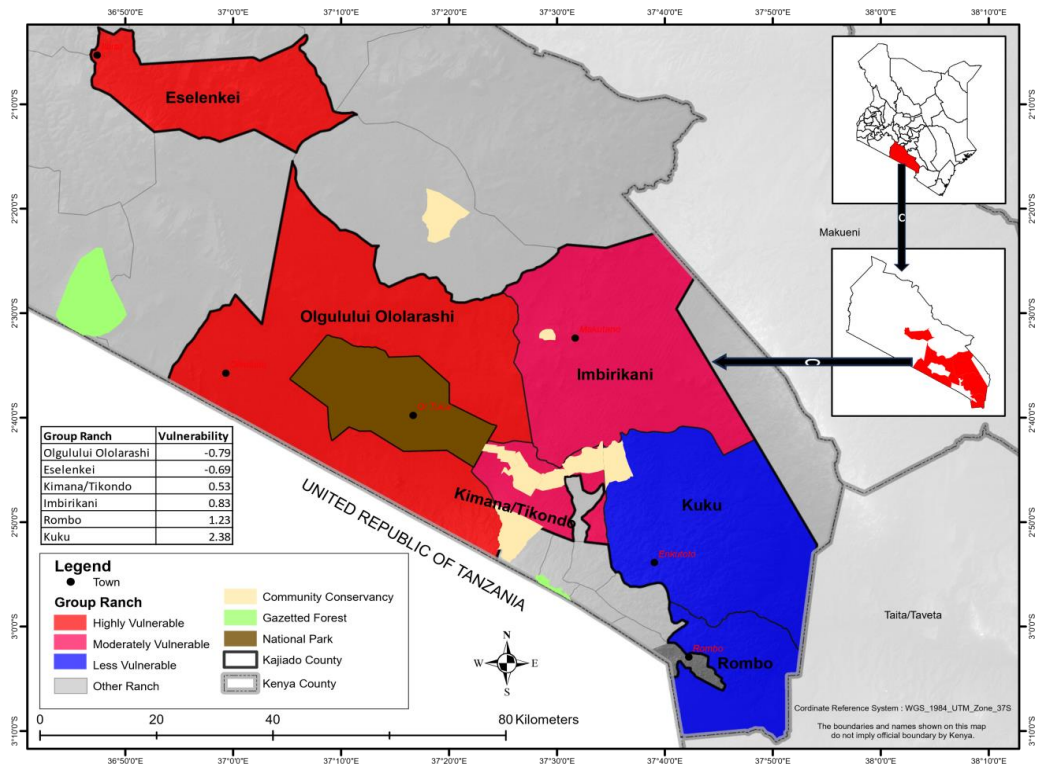


Figure 4.10 Household vulnerability Map per group ranch

Out of the six group ranches examined, the Olgulului-Olorarashi group ranch had the greatest vulnerability score due to a significant number of households having limited alternate means of income. The remaining group ranches exhibited a descending vulnerability index, starting with Eselenkei, followed by Imbirikani, Kimana, Rombo, and finally Kuku. The majority of inhabitants in Kuku ranch engaged in crop farming as a supplementary means of generating revenue, resulting in lesser animal herds. In contrast, Eselenkei and Olgulului-Olorarashi had bigger herds of cattle.

Table 4.17 Factor score for the first principal component analysis

Factors	Factor Score
Social vulnerability variables	
Gender of the respondent-HH: Male-headed	0.22917
Age of the respondent HH head: 50+ years	-0.25804
Level of education of the respondent	-0.02906
HH size: more than 9 persons	-0.29837
Experiences in the area: less than 5 years	0.039479
Person responsible to take care of animals: Both	-0.31599
Economic vulnerability variable	
Alternative source of income	-0.04414
Herd size: More than 20 livestock	0.19573
Herd structure: no of cattle	
Access to remittances: no cash transfers	-0.34130
HH employed: no member of HH employed	0.293813
HH Adaptation strategies: Those with more than 2 adaptation strategies other than pastoralism	0.100562
Livestock diversity: less than 3 livestock species	-0.15870
Environmental vulnerability variable	
Climate change: experiencing change	0.047677
Temperature: experiencing increase	0.095173
Drought: noticed increasing events	0.101335
Flood: noticed change	-0.42800
Wind: noticed unusual change	0.178153
Abbreviations: Households (HH),	

4.10 Impacts of Climate Variability on Household Livelihood

Out of the six group ranches examined, the Olgulului-Ololarashi group ranch had the greatest vulnerability score due to a significant number of households having limited alternate means of income. The remaining group ranches exhibited a descending vulnerability index, starting with Eselenkei, followed by Imbirirkani, Kimana, Rombo, and finally Kuku. The majority of inhabitants in Kuku ranch engaged in crop farming as a supplementary means of generating revenue, resulting in lesser animal herds. In contrast, Eselenkei and Olgulului-Ololarashi had bigger cow herds:

Change in dependent variable = a + b X , where

X is the explanatory variable (climate variable)

Y is the dependent variable (livelihood variable).

b is the slope of the line or regression coefficient)

a is the intercept (the value of y when x = 0)

Table 4.17 displays the outcomes of the correlation study conducted on climatic variables and indicators of livelihood. The livelihood factors exhibited both positive and negative correlations with the dependent variables. The output of milk had a substantial decrease when temperature climbed (Pearson's $r = -0.625$, $p < 0.00$) and drought occurrences were more frequent (Pearson's $r = 0.596$, $p < 0.05$). However, milk production showed a considerable rise in response to higher levels of rainfall (Pearson's $r = 0.550$, $p < 0.05$). These findings suggest. The rise in temperature and frequent droughts are associated with a decrease in productivity, which is crucial for the family's survival. Conversely, an augmentation in precipitation results in the availability of grazing land, enhanced animal well-being, and a rise in milk output.

Pal et al., (2019) noted that a correlation coefficient value (r) ranging from 0.5 to 0.8 signifies a robust link between the dependent and independent variables being correlated. Additionally, he emphasized that correlation coefficients exceeding 0.8 give rise to multicollinearity and should thus be avoided. The correlation coefficients found fell within the specified range.

The findings above were supported by the Imbirikani FGD findings, which stated that, *during the drought periods market prices for sheep, goats and cattle can be less than half as compared to the wet season when both water and pasture are readily available.*

Table 4.18 Correlations Results on Climate Variables and Six Livelihood Variables.

Livelihood variables		Temperature Variation 1989-2018	Rainfall patterns Variation 1988-2018	Frequency of drought between 1988-2018
Milk Production	Pearson Correlation	-.625**	.550	-.596
	Sig. (2-tailed)	.000	.000	.008
	N	362	362	362
Availability of water	Pearson Correlation	-.512**	.720	-.656
	Sig. (2-tailed)	.000	.000	.008
	N	362	362	362
Herd size	Pearson Correlation	-.340**	.693	-.753**
	Sig. (2-tailed)	.001	.079	.004
	N	362	362	362
Animal Reproduction	Pearson Correlation	-0.645	.472	-.663**
	Sig. (2-tailed)	.000	.003	.001
	N	362	362	362
Market Prices	Pearson Correlation	.502	.509*	-.496
	Sig. (2-tailed)	.002	.000	.003
	N	362	362	362
Livestock diseases	Pearson Correlation	0.414*	-.504*	.536
	Sig. (2-tailed)	.031	.049	.004
	N	362	362	362

** . Correlation is significant at the 0.05 level (2-tailed).(if less or greater than x)

Source: Survey data (2022)

The availability of water for residential and animal usage was a crucial determinant impacting the sustenance of families. The results from table 4.18 demonstrate a strong negative correlation between water availability and increasing temperature (Pearson r

= -0.512, $p < 0.00$), as well as the frequency of drought (Pearson $r = -0.656$, $p < 0.05$). Conversely, there is a positive and significant correlation between water availability and the amount of rainfall received (Pearson $r = 0.720$, $p < 0.05$). This indicates that the increase in temperature led to an elevated rate of evaporation, resulting in a shortage of surface water. An augmentation in precipitation resulted in improved proximity to water resources. During periods of drought, access to water was scarce.

The size of a herd in pastoralist's communities is considered an indicator of an individual's prosperity. The social position of the home head was decided by it, and it had an impact on the economic stability of the household. Consequently, the size of a herd is an appropriate indicator of a household's vulnerability to changes in climate. The data shown in Table 4.17 indicates that there is a negative correlation between herd size and long-term temperature trend (Pearson $r = -0.340$, $p < 0.00$), as well as the frequency of drought (Pearson $r = -0.753$, $p < 0.05$). On the other hand, there is a positive correlation between herd size and rainfall pattern (Pearson $r = 0.693$, $p < 0.05$). These findings suggest that when long-term temperatures increase and droughts become more frequent, cattle herd size is negatively impacted. Conversely, more rainfall is associated with larger herd numbers. Suggesting that a rise in temperature leads to a proportional decrease in the number of animals in the herd. Conversely, a reduction in temperature results in an increase in the size of the herd.

High temperature is associated with drought, and the two result in insufficient pasture and water for livestock. The health of the animals deteriorates and their productivity is reduced, hence increasing the peoples' vulnerability due to climatic stress. These findings were supported by Experts at IFAW Amboseli Office, who confirmed that *... many pastoralists lost cattle during the 2009 drought and some have never been*

able to get back to their previous economic status. These sentiments were also strongly supported by an FGD at Kimana, where a participant gave similar sentiments.

Herd sizes can expand through the processes of reproduction and restocking, which involves adding new animals to an existing herd. The process of animal reproduction is crucial for expanding the size of a herd and is hence seen as a dependable predictor of household vulnerability. The data presented in Table 4.17 indicates a negative correlation between temperature fluctuation (Pearson $r = -0.645$, $p < 0.00$) and frequency of drought (Pearson $r = -0.663$, $p < 0.05$) and animal reproduction. The rainfall pattern had a positive correlation with animal output, as indicated by a Pearson correlation coefficient of 0.472 ($p < 0.05$). There was a substantial correlation between all the climatic and livelihood factors. Therefore, in addition to the favorable rainfall pattern, rising temperature and increased frequency of drought had a detrimental effect on animal reproduction, development, and health.

The adverse impact of rising temperature and frequent droughts as well as the positive impacts of rainfall on animal reproduction were also confirmed by the findings of an FDG in Eselenkei group ranch, who observed that:

In times of drought goats, sheep and cattle become weak due to low availability of pasture and its depressed nutritional value, thus resulting to lack of breeding since their bodies become weaker for mating/pregnancy/lactation. He further emphasized that young ones born during drought season may end up dying if close attention is not given to them by their owners.

Fluctuations in meteorological conditions can impact the market prices of cattle and animal products, such as meat, milk, hinds, and skins. The market price is seen as a

measure of household vulnerability among pastoralists residing in arid and semi-arid regions. The results from table 4.17 indicate that there is a substantial positive association between temperature fluctuation (Pearson $r = 0.502$, $p < 0.00$) and frequency of drought (Pearson $r = 0.496$ $p < 0.05$) and the market prices of cattle and livestock goods. Conversely, there was a negative correlation between the rainfall pattern and market prices of animals and their goods ($r = -0.509$ $p < 0.05$). These findings suggest that a decrease in the supply of animal produce and general well-being of livestock increased market prices. The somewhat higher prices of animals and their products, meanwhile, are sufficient to allow livestock owners to replenish their stock. In times of precipitation, when numerous families own livestock and goods available for trade, market prices saw a decline.

The findings disagree with an FGD observation at Rombo where a participant said that:

There is a massive decrease in market prices for both goats and cattle in times of drought and that is during such times that selling livestock for school fees is almost counted as a loss, since not much money is received/ made in the trade.

Variations in weather circumstances can influence the market values of cattle and animal products, including meat, milk, hides, and skins. The market price is seen as an indicator of household vulnerability among pastoralists living in arid and semi-arid areas. The findings from table 4.17 demonstrate a significant positive correlation between temperature variation (Pearson $r = 0.502$, $p < 0.00$) and the occurrence of drought (Pearson $r = 0.496$ $p < 0.05$) and the market prices of cattle and animal products. In contrast, there was an inverse relationship between the rainfall pattern

and market prices of animals and their commodities ($r = -0.509$ $p < 0.05$). These data indicate that the market prices rose in response to a decline in the number of animals and animal products for sale in the marketplace. The relatively elevated prices of animals and their products, on the other hand, are adequate to enable livestock owners to restore their supply. During periods of rainfall, when many people had cattle and items for trading, market prices decreased, increasing the vulnerability of households to the uncertainties caused by climatic swings. The findings above were supported by an FGD statement given at Eselenkei group ranch, where a participant reported that “*new diseases and even old ones re-emerge during drought seasons, since livestock immunity is low, thus exposing them to vulnerability of diseases*. Some of the livestock diseases that considered important by the FDG members were *Kububuo* (foot and mouth disease), *Oloirobi* (African swine flu), and *Oltikana* (East coast fever). The names of the diseases were given in the local dialect (Maasai) but translated to English as stated in Miaron (2012).

The study conducted a model summary to ascertain to what extent the independent variables can explain changes in the dependent variables.

Table 4.19 Regression Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Milk Production	.865 ^a	.748	.739	.0249
Availability of water	.880 ^a	.774	.722	.0271
Herd size	.790 ^a	.624	.611	.0449
Animal Reproduction	.890 ^a	.792	.777	.0271
Market Prices	.855 ^a	.731	.720	.0219
Livestock diseases	.860 ^a	.740	.722	.0229

a. Predictors: (Constant), Temperature variations between 1988-2018, Rainfall patterns between 1989-2018, Frequency of drought between 1989-2018

b. Dependent Variables: Milk Production, Availability of water, Herd size, Animal Reproduction, Market Prices and Livestock diseases

Data on water availability, milk production, animal reproduction, market prices and livestock disease were measured on a continuous scale. Table 4.19 shows that the selected indices of livelihood vulnerability show that climate played a significant role in explaining the variance. About 74% of the loss in water availability was explained by climatic variables in terms of temperature and precipitation variations. These climatic factors also explained 72% of the total range in water supply. In a similar vein, the three climate parameters accounted for 61% of the variance in herd size and 78% of the variance in cattle reproduction. The three climatic parameters accounted

for 72% of the variance in the market prices of cattle and livestock products and the incidence of livestock diseases in the study region. The used regression model only partially explained the observed variability in the livelihood vulnerability indicators, accounting for just around 25% of the total. This study did not account for these traits since they are probably unrelated to the environment.

Milk production, water availability, herd size, animal reproduction, market price, and livestock diseases were among the factors analyzed in an analysis of variance to gauge the efficacy of the regression model. The calculated F values are as follows: 60.873, 62.992, 55.439, 75.176, 55.176, and 56.576. These findings all reached statistical significance at the 5% level. These results also imply a large disparity between the average variances of the various indicators of vulnerability. That's why it's reasonable to assume that weather patterns affect vulnerability indicators including milk output, water availability, herd size, animal reproduction, market prices, and livestock diseases.

Using factors such as age, gender, education level, and family size, we calculated how vulnerable different families would be to the stresses and shocks brought on by climate change. The study found that households headed by older men were better able to withstand climate change than those headed by younger men or women. Less populous households were likewise less at risk than those with more people living there.

Those households where the head of household has a high school diploma or above are better prepared to weather the consequences of climate change than those where the head of household has not completed secondary school. This is because households in which at least one member had a reliable source of income were better

equipped to weather food shortages brought on by climate change-related drought. There was a marked difference in adaptability between families whose at least one member had completed secondary school and those where no one had completed that level of schooling. Higher educated family members are more likely to be aware of and prepared to take advantage of opportunities for earning money outside the conventional employment market.

Herd size, market prices, livestock diseases, milk output, and animal reproduction were among the variables included in this analysis of vulnerability in the face of extreme weather events including floods, droughts, and the availability of water and pasture. Researchers found that during the wetter months, milk output rose, which in turn raised household income. As milk production has increased and it has become easier to get milk from one's own cows, market prices have leveled out.

As temperatures rose, surface water evaporated at a faster rate, leaving people and livestock with less to drink. As a result of transpiration water loss, plants faded to brown and eventually died. During this time, the pasture's nutritional value dropped, which had an effect on the animals' health, growth, and fertility. The animals' immune systems declined during the droughts, which had a negative impact on their health and their capacity to procreate. Discussions of the FDGs revealed an urgent need for action, both at the national and county levels, in the form of policies and careful planning. The hazards associated with climate change make this intervention essential.

Household Vulnerability Index in the Individual Group Ranches

The Amboseli Ecosystem's climatic fluctuation had varying impacts on the many community ranches. The number of animal holdings and the vulnerability score were

both greatest in the Olgulului-Ololarashi group ranch. Eselenkei group ranch was second most vulnerable to climatic fluctuation. The low herd numbers, ready access to water, and variety of different forms of livelihood income at the other group ranches of Imbirikani, Kimana-Tikondo, Rombo, and Kuku contributed to their moderate to low vulnerability indices.

The study found that in terms of allocating resources, both national and county governments, as well as policymakers, could use maps to make allocation of these resources better. The household vulnerability for each of the six group ranches highlights the need for efforts to reduce exposure to climate variability. Group ranch respondents identified household adaptive capacity building, disaster and risk management measures, and early warning systems as effective adaptation options. For the sake of fairness, it is also important to disseminate vulnerability data at the community level. It is also crucial to map vulnerability indicators throughout all of Kajiado County in order to direct targeted actions.

The study found that only 10% of the households were not vulnerable, while 34% were moderately vulnerable (index: -1.00 to 1.00) as seen in Figure 5.0. Second-placed vulnerable households had an index between -0.9 and -3.0 at 27% with high vulnerability whereas less vulnerable households numbered 29%. The results suggest that the communities in the six group ranches are not equally vulnerable to the effects of climate change because of differences in their levels of adaptation capability. Different socioeconomic factors, such as educational attainment, family size, age, and gender of primary breadwinners, were associated with varying degrees of household adaptability. Economic considerations, such as chances for alternative sources of income including crop farming, tourism, bead production and sale of bead craft items,

small company activity, and employment, also affected the adaptive ability of households. Water supply, pasture distribution, the frequency of floods, the severity of drought, and other unfavorable weather conditions all had a role in a community's ability to withstand climate change.

Since the residents at the Olgulului-Ololarashi group ranch rely so heavily on the revenue from livestock, they are especially susceptible to climate change. Nearly nine in ten (88%) of their income came from pastoring. In contrast, the Kuku group ranch had less food insecure households because to the prevalence of agricultural cultivation and small commercial operations, particularly the selling of farm products.

Eselenkei group ranch ranked second in vulnerability, only below the Imbirikani and Kimana ranches. Importantly, the results showed that the Kimana-Tikondo group ranch and the Imbirikani were the two places with the greatest numbers of available jobs. Imbirikani group ranch has the greatest proportion of homes with college graduates working in professional settings or self-employed.

Research from a variety of sources indicates that unfavorable consequences of climate change and weather patterns are making it difficult for Kenyan ASALs to recover, which in turn has a negative impact on the livelihoods of pastoralists. Kagunyu (2014) and Ombogo (2013) are two examples of such works..It is obvious from the results of this study and similar literature that immediate policy action is required at the county and national levels, with the goal of boosting awareness creation at the home level.

The study also looked at how factors including herd size, milk output, animal illness, household size, and market pricing affected people's vulnerability to economic hardship. The results demonstrated a direct/indirect connection between the aforementioned factors and household vulnerability. There was an inverse

relationship between milk output and herd size, and increasing either lowered family vulnerability. The Maasai rely heavily on milk, and when they have an abundance, they trade it in local marketplaces for other essentials. While rising milk prices were good news for people's livelihoods, rising prices for other goods meant they were more expensive and so put consumers at risk. On the other hand, animal illnesses exacerbated vulnerability since they increased family expenditures for disease management and treatment and decreased milk production. Historically, communities have relied on their own indigenous knowledge to treat livestock illnesses, but as more complicated symptoms appear, scientists have begun to suspect that global warming may be to blame. As a result, people in the area have no choice but to pay extra money to get the medication they need from Agro-vets. There have been reports of cattle contracting infections that are extremely difficult to treat, leading to the eventual loss of the herd. Households would become more vulnerable to harm as a result.

The study revealed that livestock keepers administered medications to animals that had caught a sickness. By way of considering the animal's size to dictate how much medication to provide. Six focus groups (FGDs) reported that traditional drug prescription existed to date this demonstrates the divide between individuals and communities approach different types of sickness.

The household surveys, focus groups, and interviews carried out throughout the research region all agreed that women and children were the most vulnerable during dry seasons since they stayed behind in the residential houses as men and young people moved their animals in search of pasture and water. Lactating Mothers were also reported to have equally had difficulties since food insecurity was high during such times. Government hospitals informed about the 'plumpynuts' a multivitamin

commonly given to underweight children to supplement their diets especially at the Olgulului-Ololarashi group ranch which had the highest vulnerable of them all.

Elsewhere across the Amboseli Ecosystem, boarding schools helped protect school-aged children from the risk of lacking food or further vulnerability during drought seasons. This is due to the fact that they were left in the care of instructors at boarding schools during migration, where they were guaranteed three meals a day. However, day school children also had the chance to eat at least once daily (at lunch time).

The Maasai Pastoralists, on the other hand, are known for their extreme generosity. According to all FGDs, members watch out for one another and pool their resources, including food, in times of need. So, the wealthy families actually helped out the less fortunate during the drought years (especially 2009) such is community life for them. In addition, they would provide low-wage work to disadvantaged women, which helped alleviate the effects of a food shortage and the resulting insecurity.

The neighborhood occasionally benefitted from government and well-wisher food handouts during drought seasons. Donations of beans, maize, and cooking oil dominated those of other types of food. The neediest recipients were selected by the Office of the area chief and the Village elders. Since maize porridge or a corn cake commonly referred to as ugali requires less time in the stove than whole grains, most households would grind it into maize meal. Over time, this would lessen household vulnerability.

When it comes to healthcare, several outlying communities in the area under consideration lacked access to a hospital or clinic. The vast majority of them traveled great distances on foot or with limited transit options to bring a sick loved one to the

hospital. Nonetheless, fatalities can occur when hospitals are located too far away or when transportation links are inadequate.

4.11 Adaptation Strategies at Household Level

Tactics employed at the household level from questionnaires and FGDs, included a variety of occupations besides pastoralism to make ends meet. The most intriguing finding, however, was that even after considering the current and potential future implications of climatic variability on pastoralism, most respondents still wanted to preserve it. The cattle industry is only one of many human activities that puts strain on the world's ecosystems, natural resources, and biodiversity. However, this impact on natural resources and the increased rivalry from other sectors for resources are placing increasing limits on the sector as a whole (Conradin et al., 2015). Pastoralists' means of subsistence might be as varied as the resources they have at their disposal or hope to acquire. However, the family herd is the most valuable asset in a pastoral environment. The availability of grazing pasture and irrigation facilities is closely related to the existence of herds but is secondary in significance to both. As households saw their income in cattle fall, they were more interested in acquiring resources such as cropland and forest (Gebeyehu et al., 2021). Clear and growing data shows that, at some point, the loss of water for environmental reasons will result in the loss of essential environmental services and amenities.

Most pastoralists throughout the six group ranches adapted to water constraint by moving from one location to another. The wealthier pastoralists also employed the practice of constructing water pans. One male participant at the FGDs at the Eselelenkei and Olgulului-Ololarashi group ranches mentioned that they had found "a strategic place along the river to put up a shallow well during drought seasons,"

suggesting that this practice of digging up shallow wells was widespread among the communities there. When asked how they determined the soil properties and other factors, they responded, "Traditional knowledge is what they mainly rely on."

Eighty-four percent of respondents believed the government has built dams and water pans at key locations within the region of study to adapt to climate variability. Only 19.6% of respondents claimed the government had not constructed boreholes or dams in the research regions. A participant in the FGD at Kimana corroborated this, saying, "We mainly depend on Kimana River for water for both livestock and other domestic uses." The government has not taken any proactive measures, such as the construction of strategic boreholes or water pans, to aid livestock caretakers during dry periods.

Seventy-four percent of respondents claimed the government has implemented land demarcation to prevent resource usage disputes during dry season because of difficulties connected to climatic unpredictability, such as pasture and water. As one participant at the FGD at Imbirikani put it, "There is clear demarcation between Imbirikani Group Ranch and Amboseli National Park to control livestock movement into the park," which helps to lessen human-wildlife confrontations during dry times. Seventy-four percent of respondents believed the government had not done enough to address climate unpredictability by providing for livestock insurance methods. During the FGDs at Olgulului-Ololarashi group Ranch participants said:

During the 2009 drought, most pastoralists lost livestock which was their main source of livelihood and they have never been able to recover since then. A number of known families have been living in absolute poverty since the 2009 drought. I moved my cattle to Juja during the drought and I came back owning only my herding stick and the clothes I wore then because all my cattle died;

it was very devastating for me. If we had an insurance scheme, perhaps I would have been able to diversify or restock my livestock by now.

Seventy-four percent of those polled in this study believe the government has not set up an early warning system to prepare them for the onset of disasters like floods, droughts, and disease outbreaks. At least 25.7% of respondents said that they were aware of government-mandated early warning systems.

Seventy-six percent of responders to a survey about raising knowledge of climate variability stated they were unaware of climate variability but could identify when seasons changed. Twenty-four percent of respondents have acknowledged this. The government, however, had a lot of work to do in terms of education and publicity. As a means of adapting to climate change, 80.4% of respondents indicated the local population had diversified away from dependence livestock keeping to agricultural practise.

The majority of community members (82.3%) favored using wage labor and employment as a means of adaptation, whereas just 17.7% favored using small-scale firms. An overwhelming majority (78.3%) favored livestock diversification, while 21.7% disapproved. Focus group interviewing in Kimana. One of the participants elaborated on how having a few other activities to cushion his family from adverse effects of climate change and doing some crop cultivation helped alleviate food insecurity and boost family spending power.

Another tactic was the distribution of risks among members of the same clan or among distant relatives, with 79.8 percent of respondents agreeing with this and 20.2 percent disagreeing. Seventy-nine percent of respondents stated they believe the aforementioned measures are effective at lowering vulnerability, while twenty-one percent felt otherwise. One participant in a focus group discussion (FGD) in Rombo

said, "Most of us practice crop growing both food crops and cash crops especially tomatoes which we transport to Mombasa where profits are more than compared to nearby towns."

And an interview at KWS confirmed that "most members living around Amboseli do bead work as an adaptation strategy and tourists entertainments through songs which earn them a living either as individuals or in groups."

74.3 percent of respondents replied yes, while 25.7 percent said no, when asked if they supported alternative efforts undertaken by NGOs or well-wishers. Those living in Kimana, Olingulului, and Rombo, according to a focus group discussion (FGD), have benefited economically from the involvement of nongovernmental organizations (NGOs) including IFAW, AMREF, and Child Fund. An interview at IFAW that indicated:

A number of scholarships have been awarded to both boys and girls to support them through Secondary and Tertiary levels of education while one at KWS indicated that very hot and dry seasons, KWS allows the community to feed their animals in the park up to 11am in an effort to maintain livestock health during such seasons. In addition, strategic watering points have been put to supply water for livestock in the areas of close proximity to the park.

When asked if the strategies are reducing vulnerability at household level, 79.6% agreed that most strategies were reducing vulnerability while 20.4% said the above strategies may have reduced vulnerability generally but not at the household level.

4.12 Adaptation Strategies Initiated by the Government and Community

Participants were asked to assess how much they agreed or disagreed with statements about the Amboseli ecological region's selected adaption measures. A three-point

Likert Scale was used in analysis. The scale went from "Disagree = 1" to "Agree = 3". The study arbitrarily assumed that the "Disagree" rating represented a variable with a mean rating of 0 to 1.4 on the continuous Likert scale (where 0 +Mean1.4). To illustrate a 1.5-point scale, we used the "Moderately agree" score. An "Agree" rating was interpreted to imply a variable whose mean rating was between 1.5 and 3.0 on a continuous Likert scale (1.5Mean3.0). Table 4.19 below shows the results.

Table 4.20 Adaptation strategies across GRs, Source: Survey data (2021)

Adaptation Strategy	Mean	Std.	Analysis N
The Amboseli Ecosystem has enough Boreholes that have been introduced by government	1.99	.153	362
There are Water pans in Amboseli Ecosystem region that have been introduced by government	2.06	.431	362
There is land demarcation at Amboseli Ecosystem that have been introduced by government	1.57	.407	362
There is insurance for livestock and crops in Amboseli Ecosystem that have been introduced by government	1.63	.229	362
The government has put in place installation of early warning systems as an adaptation strategy to deal with climate variability	1.69	.160	362
The Community has put in place cultivation as an adaptation strategy to deal with climate variability	2.47	.777	362
The Community has embarked on wage labour as an adaptation strategy to deal with climate variability	2.02	.375	362
The Community has embarked on small scale enterprise as an adaptation strategy to deal with climate variability	1.56	.636	362
The Community has embarked on bead making as an adaptation strategy to deal with climate variability	1.79	.602	362

Adaptation strategies at the household level across the study area were classified into three major categories i.e those initiated by the government, community initiated strategies and those that were applied at the household level. Household

questionnaires and Focused group discussions both revealed similar opinions that were subjected to person correlation and data presented in Table 4.21 below.

Table 4.21 Correlation Results on Adaptation Strategies

		Reduction of vulnerability due to climate variability stresses
Government adaptation strategies	Pearson Correlation Sig. (2-tailed)	.668 .002
Community adaptation strategies	Pearson Correlation Sig. (2-tailed)	.646** .000
Household adaptation strategies	Pearson Correlation Sig. (2-tailed)	.655 .001

The community adaption approaches had the highest coefficient of correlation ($r = 0.646$, $p < 0.001$), while the government plans demonstrated a slightly lower coefficient ($r = 0.668$, $p < 0.05$). These results indicate a significant and positive association between the two factors. A strong favorable association exists between government and community activities ($r = 0.655$, $p < 0.05$). This indicates that there was a statistically significant correlation between each adaption variable and the total score. The study's focus group discussions (FGDs) and interviews support and confirm these findings. According to a focus group discussion, there is a scarcity of grazing during dry seasons, particularly in the Rombo region. Pastoralists turned to

agricultural farming and employment for wages as a strategy to cope with the decline in their main source of income. Nasipa village, primarily known for livestock rearing, faced challenges during drought seasons when their herds were unable to graze in their usual habitats. Consequently, the villagers depended on neighboring villages such as Maili Tatu for provisions of food. In order to support this assertion, an interview conducted with KWS in Amboseli and another one at the IFAW office in Amboseli shown that the local population largely depended on bead manufacturing and tourist entertainments as strategies to deal with the unpredictable climate. The FGDs performed in both Kimana and Imbirikani revealed that the most prevalent methods of adaptation were crop growing and generating income through employment and small business enterprise.

4.13 Regression Analysis between Strategies and their Effect on Household

Vulnerability

The examined adaption techniques encompass crop cultivation, employment, small-scale entrepreneurship, tourist (hospitality) entertainment, and bead production. The categorization was divided into three groups: general adaptation techniques, community adaptation strategies, and government initiatives (at the national and county levels). An analysis was conducted to assess the efficacy of each category, with the aim of formulating practical suggestions for different stakeholders. Household-level adaptation methods were those specifically tailored to individual households, whilst community-level adaptation strategies encompassed those used by the entire community.

Government strategies refer to the specific measures implemented by the government, either at the county or national level, in the research region to mitigate the effects of

climate change and variability. Table (4.22) below shows the regression results for the three categories of adaptation strategies which tested how they reduced vulnerability at the household level.

Table 4.22 Model Summary Results on Adaptation Strategies

Model summary				
Model	r	r square	adjusted r square	std. error of the estimate
Household adaptation strategies	.799 ^a	.638	.639	.0349

a. **predictors:** (constant), government adaptation strategies, community adaptation strategies, general adaptation strategies

b. **dependent variables:** reduction of vulnerability due to climate variability stresses

Source: Survey Data (2022)

Based on the findings presented in Table 4.22, there is a positive correlation ($R = 0.799$) between the independent variable "government adaptation strategies" and the dependent variable "reduction of vulnerability due to climate variability stresses." The R-squared (R^2) value is 0.638, indicating that 63.8% of the reduction in vulnerability due to climate variability stresses in the Amboseli ecosystem (the dependent variable) can be explained and predicted by the independent variables (government adaptation strategies, community adaptation strategies, household level adaptation strategies). The remaining 36.2% is attributed to factors not considered in this study. Therefore, the model is suitable for the study.

ANOVA was employed in this study to assess the goodness of fit of the model. The results are presented in Table 4.23 below.

Table 4.23 ANOVA Results on the Goodness of Fit of the Model under Study.

Results on the goodness of fit						
Model		Sum of Squares	df	Mean Square	F	Sig.
Household level adaptation Strategies	Regression	2.309	4	.567	89.983	.000 ^b
	Residual	16.999	357	.038	62.992	
	Total	19.308	361		55.439	
a. Dependent variable: Reduction of vulnerability due to climate variability stresses.						
b. Predictors: Household level adaptation strategies						

When examining the general adaptation strategies, the generated F figures were as follows: $F = 89.983$, $F = 62.992$, $F = 55.439$. These F-values demonstrated significance at the 5% level ($\text{Sig. } F < 0.05$), indicating that the models were appropriate for defining the relationship between the dependent variable and the independent variable. This suggests that the variables selected for this study were indeed correct. General adaptation included those that were carried out at the household level strategies encompassed measures implemented at the household level, such as crop farming, small business enterprises, and employment. The study revealed that bead making was the predominant adaptation strategy, particularly in the Olgulului-Ololarashi group ranch. This was especially prominent in the Amboseli

area, which experiences a significant influx of tourists, particularly during the high season from August to December.

Eselenkei, the second group ranch in terms of livestock holdings, displayed the fewest adaptation strategies. The study suggests that residents in this area should consider adopting a pasture harvesting mechanism akin to the one implemented in Olkiramatian in Kajiado East. Additionally, there's a recommendation to increase the number of wells and water pans through collaborative efforts involving county/national governments, NGOs working in the area, and other well-wishers. This would enhance water availability and subsequently reduce vulnerability. Another proposed strategy is for the community to explore livestock insurance against drought, diseases, and famine. Additionally, they could diversify by engaging in crop cultivation during the rainy seasons. These measures can contribute to improved resilience against the impacts of climate variability.

Table 4.24 Regression results on adaptation strategies

Model		Unstandardized Coefficients		Standardized Coefficients	t-test value	Sig.
		B	Std. Error	Beta		
General adaptation Strategies	(Constant)	1.506	.026		14.585	.000
	Government adaptation strategies	.495	.141	-.037	-4.638	.000
	Community adaptation strategies	.531	.030	-.101	-.011	.000
	Household level adaptation strategies	.649	.012	.029	1.498	.000

a. Dependent Variable: Reduction of Vulnerability Due to Climate Variability Stresses,

The calculated t-value for the constant ($t = 14.585$) is highly significant at the 0.000 percent level (Sig. $p < 0.05$). This indicates that all the independent variables included in the study have a significant effect. The results demonstrate that each of these variables is statistically significant, as their p-values are below 5%. Based on the beta results, the study interprets the model as follows:

$$y = 1.506 + 0.495x_1 + 0.531x_2 + 0.649x_3$$

The beta value of 0.495 indicates that government adaptation policies have a considerable and favorable impact on lowering vulnerability caused by the stress of Climate Variability. This is due to the presence of adjacent boreholes, which decreased the distances people had to traverse in order to find water. Consequently, women, who mostly focus on household tasks, have the opportunity to engage in income-generating endeavors like bead making and small-scale commercial ventures such as selling milk. Over time, the level of vulnerability in households decreased. These data suggest that increasing Government adaptation initiatives in the area resulted in a significant 49.5% decrease in sensitivity to climate pressures.

The implementation of community adaptation measures had a notable impact on reducing sensitivity to climate-related pressures in the region, as evidenced by the beta value of 0.531. This indicates that for every one unit increase in community adaptation techniques within the Amboseli environment, there was a corresponding 0.531 decrease in vulnerability. Community adaptation options would involve using pasture management techniques, such as designating a specific area of land within the community for usage during periods of drought. Additional methods under this category encompassed the practice of clansmen sharing risks and providing annual financial assistance to school-going youngsters from disadvantaged households, which was particularly prevalent in the Olgulului-Ololarashi group ranch. Furthermore, the community excavated shallow wells at appropriate locations along seasonal rivers. Moreover, the group possessed a robust network that provided them with information on regions that had seen higher precipitation and had sufficient grazing land. This allowed them to relocate to such areas during periods of drought, which decreased their vulnerability to losses in cattle.

Community food preservation tactics were utilized to mitigate hunger during drought seasons when food supply was limited. These efforts involved preserving food using traditional knowledge.

The implementation of household adaption measures has a notable impact on mitigating vulnerability. Throughout Amboseli ecosystem there was a beta coefficient value of 0.649 which suggested that a unit increase in General adaption mechanisms within the region resulted to a 0.649 change in decrease in vulnerability due to climate variability stressors.

Common adaptation tactics encompassed the implementation of water rationing measures during periods of drought, provision of veterinary services by various entities including the County government, national government, and philanthropic organizations such as IFAW and Big Life Foundation. KWS, for instance, has been reported to engage in collaboration with the local community. This collaboration aims not only to protect their livestock from predators but also to actively participate in Community Social Responsibility initiatives. As part of these efforts, KWS assists the community by providing water transportation services during important ceremonies such as marriages, initiations, and graduations, utilizing their institutional vehicles. This fostered a really positive rapport between the Community and Kenya Wildlife Service. The implementation of these efforts leads to an enhancement in the safety of wild animals, as the community has wholeheartedly embraced wildlife conservation, resulting in the accumulation of many advantages. In addition, old prestige acts like as lion hunts by morans were now perceived differently since the society had a different perception of wild animals owing to the accompanying advantages. The community derived more employment opportunities from the local

NGOs and KWS. Young graduates obtained employment possibilities with organizations that ultimately decreased home vulnerability by providing money and making basic requirements more affordable. Additionally, it was alleged that scholarships were provided to academically talented yet financially disadvantaged pupils. The Big Life Foundation assists school-going youngsters in high school, universities, and colleges. In order to motivate and encourage hard effort, the organization provides a full scholarship to every top-performing student who successfully completes both the Kenya Certificate of Secondary Education (KCSE) and Kenya Certificate of Primary Education (KCPE) examinations. This served as a source of incentive for applicants annually, inspiring them to become more focused, diligent, and strive for excellence in their exams, with the aim of obtaining scholarships that would ultimately alleviate their families' financial problems. Furthermore, Kenya Wildlife Services has employed community rangers to oversee the interaction between domesticated animals and wild creatures during daylight hours, particularly in grazing areas. These rangers also maintain accurate records of incidents involving predation. This effort effectively halved human-wildlife confrontations by providing compensation to affected communities based on the kind and number of livestock lost, as well as the nature of the conflict. The Kenya Wildlife Service (KWS) played a crucial role in administering these compensations. This circumstance resulted in a mutually beneficial outcome for both the community and KWS. Livestock keeping continued as usual, but at the same time, efforts were made to conserve and protect wild species that were previously at risk of being killed. The provision of community benefits and enhancement of their quality of life has fostered a positive and collaborative connection between benefactors and the Community.

This has greatly facilitated research endeavors, allowing for seamless operations throughout the Amboseli Ecosystem.

CHAPTER FIVE: SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter provides a concise overview of the results, final thoughts, and suggestions for action and further research. The summary provides an overview of the main discoveries about climatic patterns in the Amboseli Ecosystem in Kajiado County and the impact of its fluctuations on the lives of the Maasai population, who rely on pastoralism. Furthermore, it emphasizes the societal, economic, and environmental elements that impact the vulnerability of families to climatic variability. Conclusions are derived from the research questions established and the discoveries obtained throughout the investigation. Consequently, suggestions have been formulated based on the interactions with individuals living in the family and direct observations conducted in the field; the literature that was studied and the results of the study. Policy and managerial actions are recommended to reduce household vulnerability and boost their adaptive potential. The study proposals seek to enhance a comprehension of the interconnection between climatic stress, exposure, and sensitivity at the household and community levels. The majority of pastoralists mostly inhabit arid and semi-arid regions, many of which are ecosystems that are very susceptible to climate fluctuation and change.

5.2 Summary of the Study Findings

The survey findings clearly indicated that several households in the study region had resorted to alternate means of earning a living. Agricultural cultivation was the predominant activity, with small business ventures, employment, tourism, and bead making, in that order of preference. However, several group ranches shown a

preference for distinct livelihood possibilities according to prevailing weather conditions and the availability of resources. Within the Rombo group ranch for example, crop cultivation exhibited a preference rate of 57%. This was due to the presence of a perennial river in Rombo, which facilitated irrigation for the population throughout the year, safe in extremely arid areas like Nasipa Village.

The Kuku group ranch has reportedly adopted crop cultivation as an alternate form of subsistence, accounting for around 46% of their overall activities. Additional means of earning a living included engaging in chicken farming and running small commercial enterprises. The Kimana-Tikondo group is also engaged in crop farming as an alternate form of living, accounting for 39% of their activities. Farmers in this area cultivated tomatoes and onions, mostly for supply to the Nairobi Marikiti Market and Mombasa. The second most favored alternative source was small commercial businesses, particularly bead production, located near Kimana gate in Amboseli National Park. The total preference for all of these combined was 61%. The Eselenkei group ranch allocated 32% of its resources to crop farming, while bead manufacture had a preference rating of 30%. However, the majority of houses in this group ranch relied only on animal husbandry.

At Imbirikani group ranch, there was a growing trend among pastoralists to engage in crop farming, with a rate of 32%, and small business ventures, with a rate of 35%. It is important to mention that the Imbirikani group ranch had the greatest degree of education within the community, resulting in a high rate of employability for at least one member of each home. As a result of the group ranch's advanced formal education system, Big Life Foundation and other non-governmental organizations have provided work chances to recent graduates, whether they hold diplomas or degrees. Additionally, Big Life Foundation has hired several young individuals as community

wildlife rangers, which has effectively decreased vulnerability within the community and households. The Olgulului-Ololarashi group ranch, which was identified as the most vulnerable, relied on cattle rearing for 88% of its livelihood. Only a limited number of homes operated small enterprises, such as selling food supplies from home-based stores. Additionally, some houses offered beverages exclusively on market days, which occur on Wednesdays and Saturdays. Some houses also employed men engaged in the commerce of purchasing and selling animals in marketplaces such as Olgulului in Kajiado South, Emali in Kajiado East, and Ibisil in Kajiado North Constituencies. The aforementioned results were derived from Focus Group Discussions (FGDs), interviews, and household questionnaires.

An examination of climate data over the last thirty years (1988-2018) has shown significant fluctuations in rainfall patterns and a little rise in average temperature. Consequently, there has been a rise in instances of drought, leading to greater vulnerability. The Mann-Kendall statistical test confirmed a notable rise in temperatures and a considerable decline in precipitation patterns. The null hypothesis, which stated that there was no substantial alteration in the pattern of temperature and precipitation in the Amboseli Ecosystem, was consequently refuted. Regression analysis revealed that several dimensions of pastoralists' livelihoods, particularly socio-economic, environmental, and biophysical dimensions, were undergoing significant transformations. The wetlands in Kimana and Rombo group ranches have seen ongoing desiccation, mostly due to intensified development in Kimana, Kuku, and Imbirkani group ranches. Consequently, this has resulted in a diminished availability of land for grazing purposes. However, there were reports of soil erosion and land degradation in the Olgulului-Ololarashi and Eselenkei group ranches. The demographic makeup of families was starting to shift due to an increase in

vulnerability. The study observed that the social makeup of households varied across several aspects, with the socioeconomic factor having the most influence. The Maasai society mostly practices polygamy, with men often having more than four wives. However, this tradition is gradually diminishing owing to the difficulties posed by climatic fluctuation and change. Undoubtedly, a smaller family with fewer dependents is easier to care for than a larger one.

Regarding Pasture and Water, respondents have noted a consistent decrease in water availability due to an increase in dry periods throughout the years. Conversely, the lack of rainfall and higher temperatures have also led to a decrease in the availability of pasture. The Amboseli Ecosystem has undergone considerable changes in land cover and the availability of tall grass over the past three decades, as evidenced by the collected Landsat pictures. The vegetation cover has decreased as a consequence of land clearance for crop growing in group ranches like Rombo, Kuku, and Imbirikani, leading to an increase in bare ground. The examination of vegetation cover through the use of Normalized Difference Vegetation Index (NDVI) indicated that changes in climate have a substantial impact on pastures. As temperatures rise, the amount of greenery in pastures decreases, leading to an increase in transpiration.

This study revealed that the distribution and availability of pasture and water were influenced by the distribution and intensity of rainfall. During seasons of drought, pastoralists migrate from one region to another in search of both abundant pasture and water sources. The years 2000 and 2009 were characterized by the most severe documented droughts. This assumption was deemed accurate as it aligns with the findings of the aforementioned survey and the meteorological data records from Kenya meteorological department, which indicated that the year 2000 saw the most severe hydrologic cycle. According to the responses pastoralists relocated from the

Amboseli basin to various regions, like as Tsavo West National Park, in order to decrease their vulnerability. However, this resulted in significant losses in terms of cattle fatalities and financial losses. The prevalence of livestock malnutrition was significant during this era, resulting in debilitation and the animals' incapacity to withstand adverse climatic circumstances. During the migration, there was a confrontation between humans and wildlife due to competition for pasture and water resources, leading to fatalities in certain cases. Despite experiencing recurrent livestock losses, these pastoralists remained resolute in their commitment to continue raising cattle, since it holds greater cultural significance to them than being only a means of living. They expressed their willingness to replenish if given the opportunity, in order to ensure the continuity of this economic activity for future generations. An individual without any animals was seen as an outcast, unless they experienced exceptional circumstances such as the loss or death of their cattle due to severe weather conditions. The null hypothesis that there was no change in Pasture and water was rejected.

In other areas, the ownership of livestock remained elevated in the Eselenkei, Olgulului-Ololarashi, and Rombo group ranches. In general, several pastoralists were contemplating decreasing their livestock count as a result of issues linked with climatic unpredictability, such as a decrease in available pasture and water. They were gradually pursuing alternative means of making a living. It is crucial to acknowledge that an increasing number of pastoralists increasingly rely on boreholes and water pans, particularly at the community level, as a result of the depletion of the seasonal rivers and marshes.

The third objective entailed examining the impact of climatic variability on household vulnerability and livelihoods. It was determined that alterations in temperature and

precipitation patterns did really impact livelihoods. This can be ascribed to a substantial decline in cattle output. The milk output, for instance, saw a significant decline, leading to vulnerability as it was a staple item in many homes. However, in contrast to other animal products, milk proved to be a lucrative source of revenue since it could be readily sold by women to adjacent urban areas, allowing them to get cash for other essential needs. A decrease in milk production thus resulted in reduced earnings and heightened vulnerability. An observable decrease in the number of animals in the herd was seen as a result of the increasing scarcity of both pasture and water. This can be ascribed to decreased animal reproductive output caused by inadequate nutrition. In contrast, calves born during drought conditions had a very low likelihood of survival. Conversely, a decrease in animal products led to a rise in market prices due to limited availability thus the law of supply and demand came into play, increased cost of products resulted to vulnerability due to increase in demand. The dry season led to a decrease in the affordability of items, resulting in increased vulnerability. The null hypothesis, which stated that climatic variability and change did not contribute to vulnerability at the household level, was disproven by accepting the alternative hypothesis.

Occurrences of severe weather phenomena, such as the 1998 El Niño, were documented. The floods resulted in extensive damage and property loss, thereby heightening vulnerability. Nevertheless, the abundance of water and pasture mitigated vulnerability by increasing milk supply and reducing market prices. Additionally, during periods of sufficient rainfall, crops thrived, leading to family stability and further reducing vulnerability.

Notable instances of severe weather conditions, such as floods, hindered education in schools when schoolchildren were unable to cross seasonal rivers owing to high water

levels. It was clear in this situation that the community did not prioritize water collecting, despite the fact that floods might be effectively handled with a good water harvesting system. The impact of climatic variability on household vulnerability was shown to be either direct or indirect. Regarding water harvesting, a participant from Imbirikani group ranch proposed that the County government collaborate with business owners to establish a scheme offering discounted rates for water tanks. This would enhance affordability and enable them to effectively manage drought periods by collecting rainwater.

In another location, a recent report by Citizen TV station regarding the evaluation of the drought conditions in Kajiado County (January 2023) unveiled that the scarcity of water was having a detrimental impact on people's means of living. It was observed that households were buying water for drinking and other household purposes (at that time) at a cost of Kshs.20 (twenty Kenyan shillings) per a 20-liter jerrican. This increased vulnerability since the most households could not afford.

The survey also indicated that inhabitants from disadvantaged families resorted to get water from alternative sources, such as dirty water pans or distant locations, exacerbating their vulnerability. In another location during dry seasons, women on most group ranches are compelled to spend a significant amount of time traversing long distances in search of water, which is a very valuable resource. As a result, their available time for pursuing alternate means of living is greatly diminished.

The study found that the adaptation measures implemented by households effectively reduced vulnerability, as tested in objective four. This is attributed to the abundance of many sources for essential necessities. Pastoralists implemented adaptation measures at the household level, but without official expertise in managing associated risks.

These adaptation tactics have allowed them to effectively manage the increasing problems posed by climate unpredictability. Crop farming was the predominant method among most group ranches, followed by small commercial businesses, employment, and bead making. These tactics were discovered to decrease vulnerability based on quantitative data obtained from answers, focus group discussions (FGDs), and interviews. An exemplary adaptation approach highlighted by several participants was the enhancement of indigenous breeds to enhance their resilience to drought and severe climate conditions.

The crop farming at Rombo, Kimana/Tikondo, and Eselenkei group ranches mostly focuses on cultivating cash crops like onions and tomatoes. These products are primarily marketed in markets outside the County, particularly in Nairobi and Mombasa. Kuku and Imbrikani group ranches cultivated staple crops such as corn and beans.

Microenterprises were conducted inside the communal land areas, particularly on designated market days. Kimana had its market days exclusively on Tuesdays, Rombo on both Mondays and Fridays, Kuku on Tuesdays and Saturdays, and Olgulului on Wednesdays and Saturdays. On market days, pastoralists would sell their animals in order to get revenue for necessities like as food, school fees, and other essential requirements.

The economy of Kajiado County was sustained by these marketplaces, since they generated income and facilitated the flow of money between other Sub Counties. It was clear that the implementation of adaptive measures was effectively decreasing vulnerability at the individual family level within the group ranches. This was apparent from the regression analysis conducted. The null hypothesis was disproven.

5.3 Conclusions

1. This study found that climate variability is taking place in Amboseli Ecosystem with positive trends in temperature and negative trends in rainfall during the last three decades (1988 – 2018). Climate variability has created stress to traditional pastoralism and adjustments are imperative. This study documented large herds of livestock as well as gradual transition from traditional pastoralism to crop farming and other non-traditional livelihood activities. The rate of transformation to alternative production systems has been slowed down by cultural attachment to livestock, limited resource capacity of households and climatic stress.
2. Availability of water and pasture is fundamental to livestock production and indeed to the success of pastoralism. This study established a strong link between climate variability and changes in the availability of water and pasture in the Amboseli Ecosystem. The six group ranches studied were endowed differently with water and pasture for livestock. Hence, their vulnerability to climate variability varied with some group ranches supporting large herds of livestock while other group ranches were struggling to support their small livestock herds. Households exhibited limited capacity to increase water supply but there were ongoing strategies to conserve and harvest water for domestic and livestock use. There were also deliberate efforts to conserve and harvest pasture to feed livestock during the dry season when natural pasture is scarce.
3. The primary source of income for pastoralists in Amboseli Ecosystem area was livestock keeping. Main sources of income through this activity included sale of livestock and animal products, such as milk, meat, hides and skin as

well as livestock manure. This study demonstrated that animal reproduction and milk production were strongly correlated with variation in climatic variables, especially rainfall. Rise in temperature caused physiological stress in lactating and young animals. Elevated rainfall was associated with availability of water and pasture as well as improved animal health and productivity. Household income from livestock products and crops improved during the periods of high rainfall. Adoption of mixed farming and paid employment also improved food security and capacity of households to restock their herds after drought.

4. The livestock sector and pastoralism in particular are hardest hit by climatic variability and stress. During this study, it was clear that the issue of climate variability is serious and was affecting pastoralists in the Amboseli Ecosystem. It was apparent that livelihood vulnerability among pastoral households were rapidly increasing because of high dependence on livestock as the main source of livelihood. Respondents in the study area identified climate-induced social and economic impacts as: rise in poverty levels, malnutrition among children below the age of five, increase in school drop outs as boys and young men would help out during migration and early marriages driven by the need to acquire wealth in the form of cows especially when families lost livestock due to famine/drought.
5. Households in the Amboseli Ecosystem adopted to some strategies in order to cope with climate variability. The adaptive strategies were diverse and were largely influenced by financial capacity of the household. The strategies included crop farming, small business enterprise, employment, tourism and bead making. These strategies reduced vulnerability to climate stress but they

were not sufficient to shield households during periods of severe drought. As a result, women respondents called for empowerment by improving their financial capacity through self-help groups that enable them to gain financial independence and access to loans to start up small business enterprises, which improve income and reduce vulnerability at the household level.

5.4 Recommendations

5.4.1 Recommendations for policy and management interventions

- a) The County Meteorological Office should create awareness of climate variability and establish an early warning system to assist pastoralists gain knowledge on temperature and precipitation variations so as to adjust accordingly and/or enable prepare for climate related disasters in the Amboseli Ecosystem and across the sub-County.
- b) Communities and other land owners living in the six group ranches should practice water conservation by constructing water pans, water recycling and reuse with the aim of increase water availability during drought seasons and reduce runoff. The National government through parastatals such as Ewaso Ngiro South development Authority can dig boreholes for the community.
- c) Pasture harvesting strategy similar to one at Olkiramatianin in Kajiado East should be put in place by the County government to increase forage availability and reduce human wildlife conflicts mostly experienced during drought seasons as has been established by the study.
- d) Livestock diversification and downsizing at the household level should be embraced to increase household income and reduce maintenance cost during drought, famine or other climate related disasters. Insurance of livestock

should be introduced by the Kajiado County government to help pastoralists recover from livestock losses through famine, migration and human wildlife conflicts.

- e) Bee keeping and manure harvesting is a potential livelihood source that can be practiced by households in addition to other existing adaptation strategies. The community has an advantage of large pieces thus such practices are easy to adopt. Manure harvesting can also be used as a source of livelihood in addition to increasing household income.
- f) That there is need to set up milk coolers at strategic locations in the group ranches to enable women acquire income by selling milk, yogurt and ghee thus decreasing vulnerability by increasing available household income. Office of the Women representative in Kajiado County should assist in such initiatives.
- g) That there is need for the County government to break the cycle of middle men during sale of livestock, livestock products, farm produce by helping pastoralists have a direct access to the markets by themselves thus reducing vulnerability.
- h)** The National and County government should have Innovative ways of creating jobs to engage the youth in productive economic activities and improve family income and work closely with area NGOs such as IFAW, Amboseli Ecosystem Trust and Big life foundation to stop early child marriages, school drop-out among young women
- i) Extension agricultural services such as treatment and management of livestock diseases through County Veterinarians should be embraced to reduce livestock loss from diseases.

- j) County government through the ministry of Environment and other well-wishers to embrace tree planting exercises during public holidays or other community special events so as to increase forest cover in line with Vision 2030 and control air quality. As such, each household can be given the responsibility of planting trees and taking care of them to maturity.
- k) The study did establish that female headed households were more vulnerable compared to those of their male counterparts. In line with this, the study recommends that more women be involved in decision making on matters community development as well as sustainable pastoralism for example pasture and water management issues besides that help them have credit accessibility through the Women representative office.

5.4.2 Recommendations for further study

- a) This study mainly focused on climate variability and livelihood vulnerability. Additional research could be conducted to identify other causes of household vulnerability at Amboseli ecosystem.
- b) A similar study focusing on crop growing residents and small-scale entrepreneurs could be carried out across the six group ranches.
- c) A Study on the influence of climate variability to human wildlife conflicts at Amboseli Ecosystem could be carried out
- d) The influence of climate variability on market prices of livestock and livestock products should also be investigated in depth.
- e) The seasonal variability in the quality of water and pasture should also be investigated as might affect livestock health and productivity.

REFERENCES

- Abate, T. (2016). Contribution of Indigenous Knowledge to Climate Change and Adaptation, Response in Southern Ethiopia. *Journal of Earth Science and Climate Change*, 7(11), 1-9.
- Abdi, S. I., Dawud, K. I., Ahmed, H. M., & Mudhaffar, M. J. (2023). Hydrological evaluation in Duhok-Semel area. *Journal of Duhok University*, 26(2), 1–11.
- AEMP. (2008-2018), (2020-2030). *Amboseli Ecosystem Management Plan*. Amboseli Ecosystem Trust. p. 12, p. 19
- Agarwal, S., Suchithra, A. S., & Singh, S. P. (2021). Analysis and interpretation of rainfall trend using Mann-Kendall's and Sen's slope method. *Indian Journal of Ecology*, 48(2), 453-457.
- Altieri, M. A., & Nicholls, C. I. (2017). The adaptation and mitigation potential of traditional agriculture in a changing climate. *Climatic Change*, 140, 33-45.
- Amendola, F., Alvarenga, M. R., Latorre, M. D., & Oliveira, M. A. (2017). Family vulnerability index to disability and dependence (FVI-DD), by social and health conditions. *Ciência & Saúde Coletiva*, 22(6), 2063-2071.
- Anas, M., Sami, M. A., Siddiqui, Z., Khatoon, K., Zeyad, M. T., & Malik, A. (2021). Impact of climate change on the incidence and transfer of food-and water-borne diseases. *Microbiomes and the Global Climate Change*, 123-144.
- Anghileri, D., Pastori, M., Marcos-Garcia, P., Umlauf, G., Crestaz, E., Seliger, R. & Carmona-Moreno, C. (2024). Global Water Challenges in Sub-Saharan Africa and how to strengthen science-policy dialogues on transboundary governance and cooperation. *Journal of Environmental Management*, 365, 121417.
- Apollo, A., & Mbah, M. F. (2021). Challenges and opportunities for climate change education (CCE) in East Africa: A critical review. *Climate*, 9(6), 93.
- Archambault, C. (2014) Young perspectives on pastoral rangeland privatization: Intimate exclusions at the intersection of youth identities. *The European Journal of Development Research* 26 (2014): 204-218.
- Arnell, N. W., Livermore, M. J., Kovats, S., Levyd, N. P., Parryf, M. L., & Gaffing, S. R. (2014). Climate and socio-economic scenarios for global-scale climate change. *Global Environmental Change* 14, 3 - 20.
- Atube, F., Malinga, G. M., Nyeko, M., Okello, D. M., Mugonola, B., Omony, G. W., & Okello-Uma, I. (2022). Farmers' perceptions of climate change, long-term variability and trends in rainfall in Apac district, northern Uganda. *CABI Agriculture and Bioscience*, 3(1), 1-16.
- Ayanlade, A., Smucker, T. A., Nyasimi, M., Sterly, H., Weldemariam, L. F., & Simpson, N. P. (2023). Complex climate change risk and emerging directions for vulnerability research in Africa. *Climate Risk Management*, 40, 100497.

- Baarsch, F., Granadillos, J. R., Hare, W., Knaus, M., Krapp, M., Schaeffer, M., & Lotze-Campen, H. (2020). The impact of climate change on incomes and convergence in Africa. *World Development*, *126*, 104699.
- Balis, L. E., Houghtaling, B., & Harden, S. M. (2022). Using implementation strategies in community settings: An introduction to the Expert Recommendations for Implementing Change (ERIC) compilation and future directions. *Translational Behavioral Medicine*, *12*(10), 965-978.
- Bbadoye, A., Ogara, W., Ouma, G., & Onono, J. (2017). Assessing vulnerability of Maasai pastoralist in Kenya to climate change and variability.
- Becerril-Piña, R., & Mastachi-Loza, C. A. (2021). Desertification: causes and countermeasures. *Life on land*, 219-231
- Becher, O., Pant, R., Verschuur, J., Mandal, A., Paltan, H., Lawless, M., & Hall, J. (2023). A multi-hazard risk framework to stress-test water supply systems to climate-related disruptions. *Earth's Future*, *11*(1), e2022EF002946.
- Belay, A., Recha, J. W., Woldeamanuel, T., & Morton, J. F. (2017). Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. *Agriculture & Food Security*, *6*, 1-13.
- Bobadoye, A. O., Ogara, W. O., Ouma, G. O., & Onono, J. O. (2014). Comparative analysis of rainfall trends in different sub-counties in Kajiado County Kenya. *American Journal of Rural Development*, *4*(6), 120-128.
- Brousse, O., Wouters, H., Demuzere, M., Thiery, W., Van de Walle, J., & van Lipzig, N. P. (2020). The local climate impact of an African city during clear-sky conditions: Implications of the recent urbanization in Kampala (Uganda). *International journal of climatology*, *40*(10), 4586-4608.
- Butler, J. R., Bergseng, A. M., Bohensky, E., Pedde, S., Aitkenhead, M., & Hamden, R. (2020). Adapting scenarios for climate adaptation: Practitioners' perspectives on a popular planning method. *Environmental Science & Policy*, *104*, 13-19.
- Butler, R. A. (2009). Brazil to Step Up Efforts to Save the Cerrado grassland. *Mongabay*.
- Byers, E., Gidden, M., Leclère, D., Balkovic, J., Burek, P., Ebi, K., & Riahi, K. (2018). Global exposure and vulnerability to multi-sector development and climate change hotspots. *Environmental Research Letters*, *13*(5), 55012.
- Conradin, K., Engesser, M., & Wiesmann, U. (2015). Four decades of World Natural Heritage: How changing protected area values influence the UNESCO label. *DIE ERDE—Journal of the Geographical Society of Berlin*, *146*(1), 34-46.
- Conway, D., Nicholls, R. J., Brown, S., Tebboth, M. G., Adger, W. N., Ahmad, B., & Wester, P. (2019). The need for bottom-up assessments of climate risks and adaptation in climate-sensitive regions. *Nature Climate Change*, *9*(7), 503-511.

- Cornwall, W. (2016). Efforts to link climate change to severe weather gain ground. *Science*, 351(6279), 1249-1250.
- Davis, C. L., & Vincent, K. (2017). *Climate risk and vulnerability: A handbook for Southern Africa*.
- Derbile, E. K., Bonye, S. Z., & Yiridomoh, G. Y. (2022). Mapping vulnerability of smallholder agriculture in Africa: Vulnerability assessment of food crop farming and climate change adaptation in Ghana. *Environmental Challenges*, 8, 100537.
- Dickinson, N., Knipschild, F., Magara, P., & Kwizera, G. (2017). Harnessing water point data to improve drinking water services. WASHNote, USAID, Coca Cola, WADA, IRC. *Rotterdam, the Netherlands*
- Dieppois, B., Rouault, M., & New, M. (2015). The impact of ENSO on Southern African rainfall in CMIP5 ocean atmosphere coupled climate models. *Climate Dynamics*, 45, 2425-2442.
- Duguma, B. (2022). Farmers' perceptions of major challenges to smallholder dairy farming in selected towns of Jimma Zone, Oromia Regional State, Ethiopia: Possible influences, impacts, coping strategies and support required. *Heliyon*, 8(6) e09717.
- Duguma, M. K., Brüntrup, M., & Tsegai, D. (2017). *Policy options for improving drought resilience and its implication for food security: the cases of Ethiopia and Kenya* (No. 98). Studies. German Institute of Development and Sustainability (IDOS).
- Dunn, R. J., Alexander, L. V., Donat, M. G., Zhang, X., Bador, M., Herold, N., & Bin Hj Yussof, M. N. A. (2020). Development of an updated global land in situ-based data set of temperature and precipitation extremes: HadEX3. *Journal of Geophysical Research: Atmospheres*, 125(16), e2019JD032263.
- Elema, S. U. (2018). *Effects of climate variability on water and pasture availability in Turbi division of Marsabit County, Kenya* (Doctoral dissertation, Doctoral dissertation). School of Environmental Studies, Kenyatta University.
- Esri. (2021). *Accuracy assessment for image classification*. face of a global threat? *Journal of Applied Ecology*, 42: 784-794.
- Etwire, P. M., Fielding, D., & Kahui, V. (2019). Climate change, crop selection and agricultural revenue in Ghana: A structural Ricardian analysis. *Journal of Agricultural Economics*, 70(2), 488-506.
- Evangelou, P. (2019). *Livestock development in Kenya's Maasailand: Pastoralists' transition to a market economy*. CRC Press.
- Fankhauser, S. (2017). Adaptation to climate change. *Annual Review of Resource Economics*, 9(1), 209-230.
- Fenta, M., Jordaan, A. & Melka, Y., 2019, Vulnerability of Southern Afar pastoralists to climate variability and change, Ethiopia, *Jàmá: Journal of Disaster Risk Studies* 11(1), a575. <https://doi.org/10.4102/jamba.v11i1.575>

- Fort, D. G., Herr, T. M., Shaw, P. L., Gutzman, K. E., & Starren, J. B. (2017). Mapping the evolving definitions of translational research. *Journal of Clinical and Translational Science*, 1(1), 60-66.
- Gebeyehu, A. K., Snelder, D., Sonneveld, B., & Abbink, J. (2021). How do agro-pastoralists cope with climate change? The case of the Nyangatom in the Lower Omo Valley of Ethiopia. *Journal of Arid Environments*, 189, 10445.
- Gemeda, D. O., Korecha, D., & Garedew, W. (2023). Determinants of climate change adaptation strategies and existing barriers in Southwestern parts of Ethiopia. *Climate Services*, 30, 100376.
- Ghil, M., & Lucarini, V. (2020). The physics of climate variability and climate change. *Reviews of Modern Physics*, 92(3), 035002.
- Giorgi, F., Raffaele, F., & Coppola, E. (2019). The response of precipitation characteristics to global warming from climate projections. *Earth System Dynamics*, 10(1), 73-89.
- Greenacre, M., Groenen, P. J., Hastie, T., d'Enza, A. I., Markos, A., & Tuzhilina, E. (2022). Principal component analysis. *Nature Reviews Methods Primers*, 2(1), 100.
- Gumel, D. Y. (2022). Assessing climate change vulnerability: A conceptual and theoretical review. *Journal of Sustainability and Environmental Management*, 1(1), 22-31.
- Hamilton, S. E., & Casey, D. (2016). Creation of a high spatio-temporal resolution global database of continuous mangrove forest cover for the 21st century (CGMFC-21). *Global Ecology and Biogeography*, 25(6), 729-738
- Howard, G., Bartram, J., Williams, A., Overbo, A., Geere, J. A., & World Health Organization. (2020). *Domestic water quantity, service level and health*. World Health Organization.
- Huang, M. T., Bai-Quan, Z. H., & Pan-Mao, Z. H. (2020). Impacts of extreme weather and climate events on desertification, land degradation and food security. *Advances in Climate Change Research*, 16(1), 17.
- Huang, S., Tang, L., Hupy, J. P., Wang, Y., & Shao, G. (2021). A commentary review on the use of normalized difference vegetation index (NDVI) in the era of popular remote sensing. *Journal of Forestry Research*, 32(1), 1-6.
- Huggins, X., Gleeson, T., Kummu, M., Zipper, S. C., Wada, Y., Troy, T. J., & Famiglietti, J. S. (2022). Hotspots for social and ecological impacts from freshwater stress and storage loss. *Nature Communications*, 13(1), 439.
- Huho, J. M., Kioko, D., Maalim, A. A., Warsame, R., & Musa, A. (2023). Adapting to Climate Change in the Semi-Arid Northern Kenya. *International Journal of Research and Innovation in Social Science*, 7(5), 74-84.
- ILRI, UNEP and ILC. (2021). *Rangelands Atlas*. International Livestock Research Institute (ILRI). Nairobi Kenya. For more information on the Atlas please contact: Fiona Flintan, Senior Scientist, ILRI (f.flintan@cigar.org)

- Innocent, N. O. (2017). *Farmers 'perceptions On the Effects of Climate Variability on Dairy Farming in Masaba North, Nyamira County, Kenya* (Doctoral Dissertation, Kenyatta University).
- Intergovernmental Panel on Climate Change. (n.d.). *Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK, and New York.
- IPCC. (2014). *Climate change 2014: Impacts, adaptation and vulnerability. Contribution of working group II to the fifth assessment report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press
- Jandreau, C., & Berkes, F. (2016). Continuity and change within the social-ecological and political landscape of the Maasai Mara, Kenya. *Pastoralism*, 6, 1-15.
- Johansson, R., Luebehusen, E., Morris, B., Shannon, H., & Meyer, S. (2015). Monitoring the impacts of weather and climate extremes on global agricultural production. *Weather and Climate Extremes*, 10, 65-71. <https://doi.org/10.1016/j.wace.2015.11.003>
- Kagunyu, A. W. (2014). *Effects of climate variability on the livelihoods and coping*.
- Kagunyu, A. W., Matiri, F. & Ngari, E. (2013). Camel Hides: Production, Marketing, and Utilization in Pastoral Regions of Northern Kenya. *Pastoralism: Research, Policy, and Practice*. Springer, 3:25.
- Kagunyu, A., Wandibba, S., & Wanjohi, J. G. (2016). *The use of indigenous climate forecasting methods by the pastoralists of Northern Kenya*. Pastoralism. Nairobi.
- Kagunyu, A., Wandibba, S., & Wanjohi, J. G. (2016). The Use of Indigenous Climate Forecasting Methods by the Pastoralists of Northern Kenya. *Pastoralism*, 6(7).
- Kaoga, J., Ouma, G., Olago, D., & Ouma, G. (2018). The Evidence of Changing Rainfall Patterns in Kajiado County, Kenya. *International Journal of Innovative Research and Development*, 7(6), 223-228.
- Kenya National Bureau of Statistics (KNBS) (2019). Kenya population and housing census. Kenya National Bureau of Statistics, Nairobi.
- Kihwele, E. S., Veldhuis, M. P., Loishooki, A., Hongoa, J. R., Hopcraft, J. G. C., Olf, H., & Wolanski, E. (2021). Upstream land-use negatively affects river flow dynamics in the Serengeti National Park. *Ecohydrology & Hydrobiology*, 21(1), 1-12.
- Klein, R. J., Midgley, G. F., Preston, B. L., Alam, M., Berkhout, F. G. H., Dow, K., & Shaw, M. R. (2014). *Climate change 2014: Impacts, adaptation, and vulnerability. IPCC fifth assessment report*, Stockholm, Sweden.
- Koech, G., Makokha, G. O., & Mundia, C. N. (2020). Climate change vulnerability assessment using a GIS modelling approach in ASAL ecosystem: A case study of Upper Ewaso Nyiro Basin, Kenya. *Modeling Earth Systems and Environment*, 6(1), 479-498.

- Kothari, C. R. (2004). *Research methodology: Methods and techniques*. New Age International.
- Kumar, S., Roshni, T., Kahya, E., & Ghorbani, M. A. (2020). Climate change projections of rainfall and its impact on the cropland suitability for rice and wheat crops in the Sone River command, Bihar. *Theoretical and Applied Climatology*, *142*, 433-451.
- Kwame, A. R., Danny, S. M., & Memory, R. (2022). The threats of climate change on water and food security in South Africa. *American Journal of Environment and Climate*, *1*(2), 73-91.
- Kwena, K., Ndegwa, W., Esilaba, A. O., Nyamwaro, S. O., Wamae, D. K., Matere, S. J., & Kibue, A. M. (2015). Climate Change Adaptation Planning in Kenya: Do Scientific Evidences Really Count? *In Adapting African agriculture to climate change*.
- Land, R. D. (2016). *Department of Rural Development and Land Reform 2016-2017*.
- Leal Filho, W., Taddese, H., Balehegn, M., Nzengya, D., Debela, N., Abayineh, A., ... & Wolf, F. (2020). Introducing experiences from African pastoralist communities to cope with climate change risks, hazards and extremes: Fostering poverty reduction. *International Journal of Disaster Risk Reduction*, *50*, 101738.
- Lee, W. T., Weisell, R., Albert, J., Tomé, D., Kurpad, A. V., & Uauy, R. (2016). Research approaches and methods for evaluating the protein quality of human foods proposed by an FAO expert working group in 2014. *The Journal of nutrition*, *146*(5), 929-932.
- Liang, L., Qin, Z., Zhao, S., Di, L., Zhang, C., Deng, M., & Liu, Z. (2016). Estimating crop chlorophyll content with hyperspectral vegetation indices and the hybrid inversion method. *International Journal of Remote Sensing*, *37*(13), 2923-2949.
- Linke, A. M., Witmer, F. D., O'Loughlin, J., McCabe, J. T., & Tir, J. (2018). Drought, local institutional contexts, and support for violence in Kenya. *Journal of Conflict Resolution*, *62*(7), 1544-1578.
- Lyon, B., & Vigaud, N. (2017). Unraveling East Africa's climate paradox. *Climate extremes: Patterns and mechanisms*, (pp.265-281). Springer.
- Macharia, D., Kaijage, E., Kindberg, L., Koech, G., Ndungu, L., Wahome, A., & Mugo, R. (2020). Mapping climate vulnerability of river basin communities in Tanzania to inform resilience interventions. *Sustainability*, *12*(10), 4102.
- Madu, I. A. (2012). Spatial vulnerability of rural households to climate change in Nigeria: Implication for internal securit. *Working paper No. 2*.
- Maishanu, S. M., Sambo, A. S., & Garba, M. M. (2019). Sustainable bioenergy development in Africa: Issues, challenges, and the way forward. *In Sustainable Bioenergy* (pp49-87). Springer.

- Matsaba, E. O., Van Selm, M., Wesonga, J. M., Goosen, H., Coninx, I., & Koomen, I. (2021). Agricultural Climate Atlas for Kajiado and Kiambu Counties, Kenya. In *Handbook of Climate Change Management: Research, Leadership, Transformation* (pp. 3-23). Cham: Springer International Publishing.
- Mganga, K. Z., Nyariki, D. M., Musimba, N. K., & Amwata, D. A. (2018). Determinants and rates of land degradation: Application of stationary time-series model to data from a semi-arid environment in Kenya. *Journal of Arid Land*, *10*, 1-11.
- Moore, S. M., Azman, A. S., Zaitchik, B. F., Mintz, E. D., Brunkard, J., Legros, D., & Lessler, J. (2017). El Niño and the shifting geography of cholera in Africa. *Proceedings of the National Academy of Sciences*, *114*(17), 4436-4441.
- Moyo, E., Nhari, L. G., Moyo, P., Murewanhema, G., & Dzinamarira, T. (2023). Health effects of climate change in Africa: A call for an improved implementation of prevention measures. *Eco-Environment & Health*, *2*(2), 74-78.
- Mugenda, O. M., & Mugenda, A. G. (2012). Research methods: Quantitative and qualitative approaches.
- Mulo, W. (2016). Effects of Climate Variability on Livestock Production and Coping Strategies in Maikona Location.
- Museleku, E. K. (2018). *Subdivision of Agricultural Land and Its Implications on Productivity: a Case of Kajiado County, Kenya* (Doctoral dissertation, University of Nairobi).
- Ngoula, F., Tekam, M. G., Kenfack, A., Tchingo, C. D. A. T., Nouboudem, S., Ngoumtsop, H., & Tchoumboue, J. (2017). Effects of heat stress on some reproductive parameters of male cavie (*Cavia porcellus*) and mitigation strategies using guava (*Psidium guajava*) leaves essential oil. *Journal of Thermal Biology*, *64*, 67-72.
- Nhemachena, C., Nhamo, L., Matchaya, G., Nhemachena, C. R., Muchara, B., Karuaihe, S. T., & Mpandeli, S. (2020). Climate Change Impacts on Water and Agriculture Sectors in Southern Africa: Threats and Opportunities for Sustainable Development. *Water*, *12*(10), 2673.
- Nicholson, S. E. (2017). *Short Rains and Long Rains*. Retrieved September 28, 2022, from EOS: <https://eos.org/editors-vox/short-rains-and-long-rains>
- Nicholson, S. E., Funk, C., & Fink, A. H. (2018). Rainfall over the African continent from the 19th through the 21st century. *Global and planetary change*, *165*, 114-127.
- Noël, C., Van Landschoot, L., Vanroelen, C., & Gadeyne, S. (2022). The public's perceptions of air pollution. What's in a name?. *Environmental Health Insights*, *16*, 11786302221123563.

- Ochieng, J., Kirimi, L., & Mathenge, M. (2016). Effects of climate variability and change on agricultural production: The case of small scale farmers in Kenya. *NJAS: Wageningen Journal of Life Sciences*, 77(1), 71-78. <https://doi.org/10.1016/j.njas.2016.03.005>
- Oertli, B. (2018). Freshwater biodiversity conservation: The role of artificial ponds in the 21st century. *Aquatic conservation: marine and freshwater ecosystems*, 28(2), 264-269.
- OLM. (2014). *Introduction to remote sensing*. Retrieved from gsp.humboldt.edu: http://gsp.humboldt.edu/olm_2019/courses/GSP_216_Online/lesson6-2/index.html
- Olofsson, P., Foody, G. M., Herold, M., Stehman, S. V., Woodcock, C. E., & Wulder, M. A. (2014). Good practices for estimating area and assessing accuracy of land change. *Remote sensing of Environment*, 148, 42-57
- Ombogo, M. O. (2013). *The Impact of Climate Variability on Pastoralism: forage dynamics and trends in cattle population in Kajiado county*. Nairobi.
- Omollo, E. O., Wasonga, O. V., Elhadi, M. Y., & Mnene, W. N. (2018). Determinants of pastoral and agro-pastoral households' participation in fodder production in Makueni and Kajiado Counties, Kenya. *Pastoralism*, 8, 1-10.
- Omotoso, A. B., Letsoalo, S., Olagunju, K. O., Tshwene, C. S., & Omotayo, A. O. (2023). Climate change and variability in sub-Saharan Africa: A systematic review of trends and impacts on agriculture. *Journal of Cleaner Production*, 414, 137487.
- Opitz-Stapleton, S., Gulati, M., Laville, C., Vazquez, M., & Tanner, T. (2023). *Building forward better: a pathway to climate-resilient development in fragile and conflict-affected situations*. International Institute for Environment and Development (IIED).
- Opiyo, F. E., Wasonga, O. V., & Nyangito, M. M. (2014). Measuring household vulnerability to climate-induced stresses in pastoral rangelands of Kenya: Implications for resilience programming. *Pastoralism*, 4(1). <https://doi.org/10.1186/s13570-014-0010-9>
- Oxford Online Dictionary, (2024) *Oxford University Press*. Retrieved from <https://www.oxfordlearnersdictionaries.com/>
- Pal, M., Bharati, P., Pal, M., & Bharati, P. (2019). Introduction to correlation and linear regression analysis. In *Applications of regression techniques*, (pp. 1-18). Springer.
- Rahmah, M., & Sulistyono, A. (2024). (2024). The integration of traditional knowledge and local wisdom in mitigating and adapting climate change: Different perspectives of indigenous peoples from Java and Bali Island. In *Traditional knowledge and climate change: An environmental impact on landscape and communities* (pp. 61-80). Springer Nature Singapore.

- Reid, K., Ross, H., Carruthers, M., Cairns, L., & Huie, K. (2020). Exploring household food security and malnutrition risk with psychosocial indicators of healthy ageing in place: The Food Train-Eat Well Age Well Partnership Project. *Journal of Global Health, 11*, 05010.
- Reid, S., Fernández-Giménez, M. E., & Galvin, K. A. (2014). Dynamics and resilience of rangelands and pastoral peoples around the globe. *Annu. Rev. Env. Resource, 39* (2014), pp. 217-242, [10.1146/annurev-environ-020713-163329](https://doi.org/10.1146/annurev-environ-020713-163329)
- Roser, D., & Seidel, C. (2016). *Climate justice: An introduction*. Routledge
- Rummukainen, M. (2016). Added value in regional climate modeling. *Wiley Interdisciplinary Reviews: Climate Change, 7*(1), 145-159.
- Rwanga, S. S., & Ndambuki, J. M. (2017). Accuracy assessment of land use/land cover classification using remote sensing and GIS. *International journal of geosciences, 8*(4). doi:10.4236/ijg.2017.84033
- Salmaso, N., Boscaini, A., Capelli, C., & Cerasino, L. (2018). Ongoing ecological shifts in a large lake are driven by climate change and eutrophication: evidences from a three-decade study in Lake Garda. *Hydrobiologia, 824*, 177-195.
- Sazib, N., Mladenova, L. E., & Bolten, J. D. (2020). Assessing the impact of ENSO on agriculture over Africa using earth observation data. *Frontiers in Sustainable Food Systems, 4*, Article 509914.
- Schipper, E. L., Ayers, J., Reid, H., Huq, S., & Rahman, A. (2014). *Community-based adaptation to climate change: Scaling it up*. Routledge.
- Shanmugam, A., Abidin, F. Z., & Tolos, H. (2018). Reliability test on factors influencing retirement confidence among working adults in Malaysia: A Pilot Study. *Asian Journal of Social Sciences & Humanities, 7*(2), 1-8.
- Simen-Kapeu, A., Lewycka, S., Ibe, O., Yeakpalah, A., Horace, J. M., Ehounou, G., & Wesseh, C. S. (2021). Strengthening the community health program in Liberia: Lessons learned from a health system approach to inform program design and better prepare for future shocks. *Journal of Global Health, 11*.
- Stocker, T. (Ed.). (2014). *Climate change 2013: the physical science basis: Working Group I contribution to the Fifth assessment report of the Intergovernmental Panel on Climate Change*. Cambridge university press. *Stige National Academy of science of USA, 103*(9).
- Tesso, G., Emanu, B., & Ketema, M. (2018). Analysis of vulnerability and resilience to climate change induced shocks in North Shewa, Ethiopia', *Agricultural Sciences, 3-16*.
- United Nations Framework Convention on Climate Change. (n.d.). *About the UNFCCC*. Retrieved from <https://unfccc.int>

- Van der Geest, K., & Warner, K. (2019). Loss and damage in the IPCC Fifth Assessment Report (Working Group II): A text-mining analysis. *Climate Policy*, 1–14. <https://doi:10.1080/14693062.2019.1704678>
- Van Loon, A. F., Rangelcroft, S., Coxon, G., Werner, M., Wanders, N., Di Baldassarre, G., & Van Lanen, H. A. (2022). Streamflow droughts aggravated by human activities despite management. *Environmental Research Letters*, 17(4), 044059.
- Van Weezel, S. (2019). On climate and conflict: Precipitation decline and communal conflict in Ethiopia and Kenya. *Journal of Peace Research*, 56(4), 514-528
- Varis, O., Marko K., & Kummu, M (2017). Four dimensions of water security with a case of the indirect role of water in global food security. *Water Security* ,1, 36-45.
- Verbeek, L., Gall, A., Hillebrand, H., & Striebel, M. (2018). Warming and oligotrophication cause shifts in freshwater phytoplankton communities. *Global Change Biology*, 24(10), 4532-4543.
- Viladrich, C., Angulo-Brunet, A., & Doval, E. (2017). A journey around alpha and omega to estimate internal consistency reliability. *Anales de psicología*, 33(3), 755-782.
- Walker, S. E., Smith, E. A., Bennett, N., Bannister, E., Narayana, A., Nuckols, T., & Bailey, K. M. (2024). Defining and conceptualizing equity and justice in climate adaptation. *Global Environmental Change*, 87, 102885.
- Wambua, C. (2019). The Kenya climate change act 2016: Emerging lessons from a pioneer law. *Climate Change Law Review*, 13, 257-278.
- Warren, R., Price, J., & Jenkins, R. (2021). Climate change and terrestrial biodiversity. In *The impacts of climate change* (pp. 85-114). Elsevier.
- Western, D., Tyrrell, P., Brehony, P., Russell, S., Western, G., & Kamanga, J. (2020). Conservation from the inside-out: Winning space and a place for wildlife in working landscapes. *People and Nature*, 2(2), 279-291.
- Wichern, J., Descheemaeker, K., Giller, K. E., Ebanyat, P., Taulya, G., & van Wijk, M. T. (2019). Vulnerability and adaptation options to climate change for rural livelihoods: A country-wide analysis for Uganda. *Agricultural Systems*, 176, 102663.
- World Health Organization (2023) *Report on climate change*. Retrieved from <https://www.who.int>
- Wright, C. Y., Kapwata, T., Du Preez, D. J., Wernecke, B., Garland, R. M., Nkosi, V., & Norval, M. (2021). Major climate change-induced risks to human health in South Africa. *Environmental Research*, 196, 110973.
- Yusuf, N., Okoh, D., Musa, I., Adedaja, S., & Said, R. (2017). A study of the surface air temperature variations in Nigeria. *The Open Atmospheric Science Journal*, 11(1).

- Zelege, T., Beyene, F., Deressa, T., Yousuf, J., & Kebede, T. (2021). Vulnerability of smallholder farmers to climate change-induced shocks in East Hararghe Zone, Ethiopia. *Sustainability*, *13*(4), 2162.
- Zhao, T., & Dai, A. (2022). CMIP6 model-projected hydroclimatic and drought changes and their causes in the twenty-first century. *Journal of Climate*, *35*(3), 897-921.
- Zulfiqar, F., Zubair, M., & Ullah, R. (2021). Climate-induced water scarcity and the effectiveness of community-based water resource management. In *Natural Resource Governance in Asia* (pp. 343-351). Elsevier.

- 5) How many years have you lived in this region a) 0-5 () b) 6-10 c) 11-15 d) 16-20 e) Over 20years

Section B: Information on pastoralism as a source of livelihood

- 6) Are you a Pastoralists a) Yes b) No
- 7) How many years of Pastoralism do you have?-----
- 8) What type of livestock do you keep? a) Cattle () b) Shoats () c) Donkeys d) All of the above () e) None of the above ()
- 9) How many of (8) above do you have in numbers a) Cattle----- b) Sheep----- c) Goats ----- d) Donkeys-----
- 10) How many livestock should one own in this area to be considered wealthy? a) Cattle----- b) Sheep----- c) Goats ----- d) Donkeys-----
- 11) Do you have any other source of income a) Yes..... B) No.....
If yes please specify a) Cultivation b) Wage labor c) Small business enterprise.....
- 12) Apart from yourself, is any other member of your household involved in an alternative source of income apart from pastoralism? a) Yes () b) No ()
If yes, Specify-----
- 13) Whose responsibility is it to take care of the livestock? A) Man b) Woman c) Both.... Why is this the case-----
- 14) Who in many cases is involved in doing other income generating activities a) Man b) Woman c) Adult children Why is this the case-----
- 15) Traditionally what are the roles of a man (respondent to mention all that they know)
a-----

- b)-----
- c)-----
- d)-----
- e)-----
- f)-----

16)) What are the roles of a woman (respondent to mention all that they know)

- a)-----
- b)-----
- c)-----
- d)-----
- e)-----

Section C: Climate variability indicators (respondents to give as much history as they can)

17) Based on your memories, and current observations, what is the state of the following between 1989-202019

- a) Temperature variations -----

- b) Rainfall patterns -----

- c) Frequency of drought -----

- d) Occurrences of floods -----

- e) Availability of water (for livestock use and domestic use)-----

- f) Weather patterns-----

- g) Livestock diseases -----

- h) Wind patterns -----

**Section D: Climate variability impact on pastoralism as a source of livelihood
between the years 1989-2019**

18) Impact of temperature variations on

- a) Availability of water i) More available () ii) Less available () iii)
No change

- b) Pasture availability i) Increased () ii) Decreased iii)
 No change
- c) Milk production i) Increased(by how many liters-----ii)
 Decreased (by how many liters) ----- iii) No change-----
 -
- d) Herd Size i) Increased (by what numbers)----- ii)
 Decreased (by what number----- iii) No change -----

- e) Animal Reproduction i) Increased----- ii) Decreased-----
 ----- Iii) No Change-----
- f) Market Prices i) Increased----- ii) Decreased-----
 ----- iii) No change-----
- g) Human Wildlife conflicts i) Increased----- ii) Decreased-----
 ----- iii) No change----

19) Impact of Rainfall patterns on

- a) Availability of water i) More available () ii) Less available () iii)
 No change
- b) Pasture availability i) Increased () ii) Decreased iii)
 No change
- c) Milk production i) Increased(by how many liters-----ii)
 Decreased (by how many liters) ----- iii) No change-----
 -
- d) Herd Size i) Increased (by what numbers)----- ii)
 Decreased (by what number----- iii) No change -----

- e) Animal Reproduction i) Increased----- ii) Decreased-----
----- Iii) No Change-----
- f) Market Prices i) Increased----- ii) Decreased-----
----- iii) No change-----
- g) Human Wildlife conflicts i) Increased----- ii) Decreased-----
----- iii) No change----

20) Impact of Frequency of droughts on

- a) Availability of water i) More available () ii) Less available () iii)
No change
- b) Pasture availability i) Increased () ii) Decreased iii)
No change
- c) Milk production i) Increased(by how many liters-----ii)
Decreased (by how many liters) ----- iii) No change-----
-
- d) Herd Size i) Increased (by what numbers)----- ii)
Decreased (by what number----- iii) No change -----

- e) Animal Reproduction i) Increased----- ii) Decreased-----
----- Iii) No Change-----
- f) Market Prices i) Increased----- ii) Decreased-----
----- iii) No change-----
- g) Human Wildlife conflicts i) Increased----- ii) Decreased-----
----- iii) No change----

21) Impact of changes in Weather patterns on

- a) Availability of water i) More available () ii) Less available () iii) No change
- b) Pasture availability i) Increased () ii) Decreased iii) No change
- c) Milk production i) Increased(by how many liters-----ii) Decreased (by how many liters) ----- iii) No change-----
-
- d) Herd Size i) Increased (by what numbers)----- ii) Decreased (by what number----- iii) No change -----

- e) Animal Reproduction i) Increased----- ii) Decreased-----
----- iii) No Change-----
- f) Market Prices i) Increased----- ii) Decreased-----
----- iii) No change-----
- g) Human Wildlife conflicts i) Increased----- ii) Decreased-----
----- iii) No change----

22) Impact of livestock diseases on

- a) Availability of water i) More available () ii) Less available () iii) No change
- b) Pasture availability i) Increased () ii) Decreased iii) No change
- c) Milk production i) Increased(by how many liters-----ii) Decreased (by how many liters) ----- iii) No change-----

- g) Human Wildlife conflicts i) Increased----- ii) Decreased-----
----- iii) No change----

Section E: What adaptation strategies have been put in place to deal with climate variability (here the respondent is encouraged to mention the exact area where these strategies are found/can be seen)

24) By the government

- a) Putting up Boreholes
- b) Construction of dams/water pans
- c) Land demarcation
- d) Livestock insurance
- e) Installation of early warning systems
- f) Awareness creation on climate variability indicators

25) By the community

- a) Cultivation (mention type of crop(s))-----

- b) Wage labor (mention the nature/type of job)-----

- c) Small business enterprise. (Mention which one) -----

d) Bead making/ Tourists entertainment through songs, dance etc-----

e) Livestock diversification -----

f) Risk sharing among i) Clan members ii) Relatives iii) Friends

26) Are all the above strategies reducing vulnerability at household level? If yes, how?

27) Any there any other strategy initiated by other bodies (for example NGOs/Well-wishers) a) Yes-----b) No----- if yes, which ones-

28) Are the above (27) reducing vulnerability? If yes, how? (give as much response as possible)

Section F: Indicators of gender inequality

29) In your opinion does gender inequality exists among the Maasai Pastoralists?

30) Yes----- b) No-----

31) What are the indicators of gender inequality in this area?

- a) Employment opportunities
- b) School going children (boys :girls ratio)
- c) Income spending
- d) FGM
- e) Early childhood Marriages

- f) Early pregnancies
- g) School completion rate among girls
- h) Involvement in gainful employment

32) Please elaborate your answer.....

33) Who makes decisions in the Maasai household regarding the following

- a) Ownership of livestock
- b) Sale/Restocking of livestock
- c) Income consumption patterns
- d) Family planning
- e) School going children
- f) Land ownership
- g) Ownership of other income generating activities
- h) Voting rights

34) In your opinion, are the adaptation strategies mentioned in (25) above causing gender inequality? If yes, how?

35) In your opinion how can gender equality be achieved among these pastoral households

36) What do you think the following institutions should do to improve the role of women in various development activities among pastoralists?

- a) National Government.....
- b) County Government.....
- c) Community.....
- d) NGOs.....
- e) Others, specify.....

Section G: Environmental implications of climate variability coping mechanisms

37) What environmental implications does the following coping mechanism have

a) Cultivation-----

b) Wage labor -----

c) Small business enterprise -----

d) Construction of boreholes -----

e) Constructions of dams/water pans -----

-----Livestock insurance-----

Appendix II: Interview Guide

Interviews shall be carried out at Kenya Wildlife service's Amboseli Headquarters, Olgulului-Ololarashi group ranch office, Amboseli Trust for Elephants and International Fund for Animal Welfare Kenya and Big life foundation. This category was purposely sampled based on the assumption that they have from time to time interacted with pastoralists in the study area hence rich in information.

Questions


1. From when did your organization start operation in this area?
2. In your records/observation has there been variations of the following within this area?
 - a) Temperature
 - b) Rainfall patterns
 - c) Frequency of drought
 - d) Weather patterns
 - e) Livestock diseases
3. Do you think the above indicators have impacted pastoralism in this area? If yes how?
4. From your own experiences and interactions with Pastoralists here, have there been any human wildlife conflicts arising from the five indicators in question (2) above?


If yes, please tell us the nature of conflict, frequency, its resolution mechanism and if your organization has been directly involved in any resolution mechanism

5. In your own opinion is Pastoralism in this area sustainable? if yes, why? If no, why?

- 1) At what point do you interact with pastoralists?
- 2) Has your organization contributed to the livelihoods of pastoralists in this area? If yes, please state how.
- 3) Are there any observable alternative sources of income by pastoralists or the government in this area? If yes, kindly specify
- 4) In your own knowledge, has the national or county government put up any coping mechanism to impacts of climate variability to pastoralism? If yes, which ones.
- 5) Do you think adaptation strategies put in place are reducing vulnerability at household level, if yes how?


Appendix III: Research License


REPUBLIC OF KENYA
 NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION


NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: 803152 **Date of Issue: 12/July/2021**


RESEARCH LICENSE




This is to Certify that Ms. FAITH RESIATIO OLOITIPITIP of Kenyatta University, has been licensed to conduct research in Kajindo on the topic: CLIMATE VARIABILITY AND LIVELIHOOD VULNERABILITY OF THE MAASAI PASTORALISTS OF KAJIADO COUNTY, KENYA for the period ending : 12/July/2022.

License No: NACOSTI/P/21/11664

803152
Applicant Identification Number


Director General
NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

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THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013

The Grant of Research Licenses is Guided by the Science, Technology and Innovation (Research Licensing) Regulations, 2014


CONDITIONS

1. The License is valid for the proposed research, location and specified period
2. The License any rights thereunder are non-transferable
3. The Licensee shall inform the relevant County Director of Education, County Commissioner and County Governor before commencement of the research
4. Excavation, filming and collection of specimens are subject to further necessary clearance from relevant Government Agencies
5. The License does not give authority to transfer research materials
6. NACOSTI may monitor and evaluate the licensed research project
7. The Licensee shall submit one hard copy and upload a soft copy of their final report (thesis) within one year of completion of the research
8. NACOSTI reserves the right to modify the conditions of the License including cancellation without prior notice

National Commission for Science, Technology and Innovation
off Waiyaki Way, Upper Kabete,
P. O. Box 30623, 00100 Nairobi, KENYA
Land line: 020 4007000, 020 2241349, 020 3310571, 020 8001077
Mobile: 0713 788 787 / 0735 404 245
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Website: www.nacosti.go.ke

Appendix IV: Kenyatta University's Research Authorization

4


KENYATTA UNIVERSITY
GRADUATE SCHOOL

E-mail: kulpw@yahoo.com
dean_graduate@ku.ac.ke
Website: www.ku.ac.ke

P.O. Box 43844, 00100
NAIROBI, KENYA
Tel. 810901 Ext. 57530

Internal Memo

FROM: Dean, Graduate School
DATE: 13th April, 2021

TO: Ms. Faith O. Resiatio
C/o Department of Environ. Science & Education
KENYATTA UNIVERSITY
REF: N85/28515/18

SUBJECT: APPROVAL OF RESEARCH PROPOSAL


This is to inform you that the Graduate School Board at its meeting 31st March, 2021 approved your Ph.D. Research Proposal entitled "Climate Variability and Livelihood Vulnerability of the Maasai Pastoralists in Kajiado County, Kenya".

You may now proceed with your Data collection, subject to clearance with the Director General, National Commission for Science, Technology & Innovation.

As you embark on your data collection, please note that you will be required to submit to Graduate School completed supervision Tracking and Progress Report Forms. The Forms are available at the University's Website under Graduate School webpage downloads.

By copy of this letter, the Registrar (Academic) is hereby requested to grant you substantive registration for your Ph.D. studies.

Thank you.


REUBEN MURIUKI
FOR: DEAN, GRADUATE SCHOOL.

e.c. Chairman, Department of Environmental Science & Education
Registrar (Academic) Att: Mr. Richard Chweya

Supervisors:

1. Dr. Cecilia Gichuki
C/o Dept of Environmental Science & Education
KENYATTA UNIVERSITY
2. Dr. Ezekiel Ndunda
C/o Dept of Environmental Science & Education
KENYATTA UNIVERSITY

EM/cao

Appendix V: Research Authorization from County Director of Education



REPUBLIC OF KENYA
MINISTRY OF EDUCATION
State Department of Early Learning and Basic Education

Email: kajiadocde@gmail.com
When replying please quote

COUNTY DIRECTOR OF EDUCATION
KAJIADO COUNTY
P.O. BOX 33-01100
KAJIADO

Ref: **KJD/C/R.3/VOL I (302)**

29th October, 2021

Faith Resiatio Oloiptip
Kenyatta University
P.o Box 43844-00100
NAIROBI

RE: RESEARCH AUTHORIZATION

Reference is made to a letter from National Commission for Science, Technology and Innovation **Ref. No. NACOSTI/P/21/11664** dated 12th July, 2021.

Authority is hereby granted to you to conduct your research on "**Climate Change Variability and Livelihood Vulnerability of the Maasai pastoralists of Loitokitok Sub-County, in Kajiado County**", for the period ending 12th July, 2022.

On completion of the research, you are expected to submit **a copy** of the research report/thesis to our office.

JOYCE SANKOK
For: COUNTY DIRECTOR OF EDUCATION
KAJIADO



Appendix VI: Correlation on climate variability and livestock diseases

Model	Unstandardized Coefficients		Standardized Coefficients Beta	t	Sig.
	B	Std. Error			
(Constant)	1.336	.112		11.890	.000
Based on your memories, and current observations, what is the state of Temperature variations between 1989-2018	-.017	.018	-.049	-.949	.343
Based on your memories, and current observations, what is the state of Rainfall patterns between 1989-2018	-.040	.026	-.080	-1.524	.128
Based on your memories, and current observations, what is the state of Frequency of drought between 1989-2018	-.030	.029	-.055	-1.045	.297
Based on your memories, and current observations, what is the state of Occurrences of floods between 1989-2018	.086	.026	.177	3.282	.001

Appendix VI: Pearson's Correlations on Adaptation Strategies

		The government has put in place boreholes as an adaptation strategy to deal with climate variability	The government has put in place Construction of dams/water pans as an adaptation strategy to deal with climate variability	The government has put in place Land demarcation as an adaptation strategy to deal with climate variability	The government has put in place Livestock insurance as an adaptation strategy to deal with climate variability	The government has put in place installation of early warning systems as an adaptation strategy to deal with climate variability	The government has put in place Awareness creation on climate variability indicators as an adaptation strategy to deal with climate variability	RGVulnerability
The government has put in place boreholes as an adaptation strategy to deal with climate variability	Pearson Correlation	1	.920**	.037	.100	.033	.191**	-.042
	Sig. (2-tailed)		.000	.489	.058	.529	.000	.429
	N	362	362	362	362	362	362	362
The government has put in place Construction of dams/water pans as an adaptation strategy to deal with climate variability	Pearson Correlation	.920**	1	.015	.006	.012	.227**	-.056
	Sig. (2-tailed)	.000		.772	.914	.819	.000	.292
	N	362	362	362	362	362	362	362
The government has put in place Land demarcation as an adaptation strategy to deal with climate variability	Pearson Correlation	.037	.015	1	.965**	.993**	-.031	.201**
	Sig. (2-tailed)	.489	.772		.000	.000	.552	.000
	N	362	362	362	362	362	362	362

The government has put in place Livestock insurance as an adaptation strategy to deal with climate variability	Pearson Correlation	.100	.006	.965**	1	.958**	-.041	.201**
	Sig. (2-tailed)	.058	.914	.000		.000	.436	.000
	N	362	362	362	362	362	362	362
The government has put in place installation of early warning systems as an adaptation strategy to deal with climate variability	Pearson Correlation	.033	.012	.993**	.958**	1	-.035	.202**
	Sig. (2-tailed)	.529	.819	.000	.000		.509	.000
	N	362	362	362	362	362	362	362
The government has put in place Awareness creation on climate variability indicators as an adaptation strategy to deal with climate variability	Pearson Correlation	.191**	.227**	-.031	-.041	-.035	1	-.089
	Sig. (2-tailed)	.000	.000	.552	.436	.509		.092
	N	362	362	362	362	362	362	362
RGVulnerability	Pearson Correlation	-.042	-.056	.201**	.201**	.202**	-.089	1
	Sig. (2-tailed)	.429	.292	.000	.000	.000	.092	
	N	362	362	362	362	362	362	362

** . Correlation is significant at the 0.01 level (2-tailed).

Appendix VII: ANOVA Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.696	.051		13.752	.000
	The government has put in place boreholes as an adaptation strategy to deal with climate variability	-.016	.089	-.035	-.185	.854
	The government has put in place Construction of dams/water pans as an adaptation strategy to deal with climate variability	-.004	.092	-.009	-.048	.962
	The government has put in place Land demarcation as an adaptation strategy to deal with climate variability	-.028	.233	-.062	-.121	.903
	The government has put in place Livestock insurance as an adaptation strategy to deal with climate variability	.056	.125	.124	.444	.657
	The government has put in place installation of early warning systems as an adaptation strategy to deal with climate variability	.065	.197	.143	.332	.740
	The government has put in place Awareness creation on climate variability indicators as an adaptation strategy to deal with climate variability	-.034	.025	-.072	-1.350	.178
	a. Dependent Variable: RGVulnerability					

Appendix VIII: Correlation between Climate Variability and Milk Production

		Milk Production	Based on your memories, and current observations, what is the state of Temperature variations between 1989-2018	Based on your memories, and current observations, what is the state of Rainfall patterns between 1989-2018	Based on your memories, and current observations, what is the state of Frequency of drought between 1989-2018	Based on your memories, and current observations, what is the state of Occurrences of floods between 1989-2018
Milk Production	Pearson Correlation	1	-.225**	.020	.096	-.120*
	Sig. (2-tailed)		.000	.710	.068	.022
	N	362	362	362	362	362
Based on your memories, and current observations, what is the state of Temperature variations between 1989-2018	Pearson Correlation	-.225**	1	.014	.048	-.069
	Sig. (2-tailed)	.000		.786	.365	.189
	N	362	362	362	362	362
Based on your memories, and current observations, what is the state of Rainfall patterns between 1989-2018	Pearson Correlation	.020	.014	1	.035	-.177**
	Sig. (2-tailed)	.710	.786		.506	.001
	N	362	362	362	362	362
Based on your memories,	Pearson Correlation	.096	.048	.035	1	-.243**

and current observations, what is the state of Frequency of drought between 1989-2018	Sig. (2-tailed)	.068	.365	.506		.000
	N	362	362	362	362	362
Based on your memories, and current observations, what is the state of Occurrences of floods between 1989-2018	Pearson Correlation	-.120*	-.069	-.177**	-.243**	1
	Sig. (2-tailed)	.022	.189	.001	.000	
	N	362	362	362	362	362

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Appendix IX: Quantitative Results on Climate Variability Indicators from Respondent's

	Decreased	No Change	Increased
Based on your memories, and current observations, what is the state of Temperature variations between 1989-2018	51(14.1%)	57(15.7%)	254(70.2%)
Based on your memories, and current observations, what is the state of Rainfall patterns between 1989-2018	273(75.4%)	78(21.5%)	11(3.0%)
Based on your memories, and current observations, what is the state of Frequency of drought between 1989-2018	5(1.4%)	88(24.3%)	269(74.3%)
Based on your memories, and current observations, what is the state of Occurrences of floods between 1989-2018	265(73.2%)	84(23.2%)	13(3.6%)
Based on your memories, and current observations, what is the state of livestock DISEASES between 1989-2018	37(10.2%)	25(6.9%)	300(82.9%)
Based on your memories, and current observations, what is the state of Availability of water (for livestock use and domestic use) between 1989-2018	263(72.7%)	70(19.3%)	29(8.0%)
Based on your memories, and current observations, what is the state livestock DISEASES 1989-2018	21(5.8%)	36(9.9%)	305(84.3%)
Based on your memories, and current observations,	28(7.7%)	54(14.9%)	280(77.3%)

what is the state
CONFLICTS

Based on your memories, and current observations, what is the state of Rainfall patterns between 1989-2018	273(75.4%)	78(21.5%)	11(3.0%)
Based on your memories, and current observations, what is the state of Frequency of drought between 1989-2018	20(5.5%)	85(23.5%)	257(71%)
Based on your memories, and current observations, what is the state of Occurrences of floods between 1989-2018	265(73.2%)	84(23.2%)	13(3.6%)
Based on your memories, and current observations, what is the state of Availability of water (for livestock use and domestic use) between 1989-2018	263(72.7%)	70(19.3%)	29(8%)
Based on your memories, and current observations, what is the state of Weather patterns between 1989-2018	273(75.4%)	78(21.5%)	11(3%)
Based on your memories, and current observations, what is the state of Livestock diseases between 1989-2018	257(71%)	85(23.5%)	20(5.5%)
Based on your memories, and current observations, what is the state of Wind patterns between 1989-2018	265(73.2%)	84(23.2%)	13(3.6%)

Appendix X: NDVI Values on Change in Vegetation Cover

Class Period	Thick Vegetation		Vegetation		Rangelands		Bare land	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
1988- 1998	165174.7 5	33.9 5	151571.5 2	31.1 5	93667.14	19.2 5	66864.96	13.7 4
1998- 2008	26757.27	5.5	131902.3 8	27.1 1	228672	47	74887.47	15.3 9
2008- 2018	23764.32	4.88	16859.79	3.46	215889.1 2	44.3 8	191247.4 8	39.3

Appendix XI: Respondent's Perception on Rainfall patterns

STATEMENT-RAINFALL PATTERNS	No Change	Less Available	More Available
Impact of Rainfall patterns on Pasture availability	245(67.7%)	86(23.8%)	31(8.6%)
Impact of Rainfall patterns on Milk production	306(84.5%)	45(12.4%)	11(3.0%)
Impact of Rainfall patterns on Herd Size	261(72.1%)	86(23.8%)	15(4.1%)
Impact of Rainfall patterns on Animal Reproduction	298(82.3%)	64(17.7%)	0(0%)
Impact of Rainfall patterns on Market Prices	256(70.7%)	84(23.2%)	22(6.1%)
Impact of Rainfall Patterns on Human Wildlife conflicts	280(77.3%)	77(21.3%)	5(1.4%)

Appendix XII: Respondents Perception on Change in Pasture and water sources

STATEMENT - WATER SOURCES	No Change	Less Available	More Available
Impact of water sources on Availability of water	291(80.4%)	71(19.6%)	0(0%)
Impact of water sources availability on Pasture availability	281(77.6%)	77(21.3%)	4(1.1%)
Impact of water sources availability on Milk production	306(84.5%)	51(14.1%)	5(1.4%)
Impact of water sources availability on Herd Size	284(78.5%)	77(21.3%)	1(.3%)
Impact of water sources availability on Animal Reproduction	276(74.3%)	80(22.1%)	6(1.7%)
Impact of water sources availability on Market Prices	293(80.9%)	59(16.3%)	10(20.8%)
Impact of water sources availability on Human Wildlife conflicts	286(79.0%)	73(20.2%)	3(0.8%)

On the impact of water availability to milk production, it was discovered that there was a direct relationship between water availability and milk production where milk was more available when there was more available water for animals to drink with 84.5% being in agreement while 14.1% said there was no change and 1.4% thinking there was a reduction in milk production due to availability of water sources.

On the analysis of water availability to herd size, most respondents were of the opinion that herd size increased with available water sources at 78.5% while those with the contrary opinion was at 3%. Those who thought there was no change was 21.3% .This could mean pastoralists become more comfortable with keeping more livestock when water sources are certain and nearer as compared to when the same sources are far and less available\

Appendix XIII: Adaptation Strategies

STATEMENT - STRATEGIES	YES	NO
The government has put in place boreholes as an adaptation strategy to deal with climate variability	287(79.3%)	75(20.7)
The government has put in place Construction of dams/water pans as an adaptation strategy to deal with climate variability	291(80.4%)	71(19.6%)
The government has put in place Land demarcation as an adaptation strategy to deal with climate variability	270(74.6%)	92(25.4%)
The government has put in place Livestock insurance as an adaptation strategy to deal with climate variability	268(74%)	93(26%)
The government has put in place installation of early warning systems as an adaptation strategy to deal with climate variability	269(74.3%)	93(25.7%)
The government has put in place Awareness creation on climate variability indicators as an adaptation strategy to deal with climate variability	275(76.0%)	87(24%)
The Community has put in place cultivation as an adaptation strategy to deal with climate variability	291(80.4%)	72(19.6%)
The Community has embarked on wage labor as an adaptation strategy to deal with climate variability	298(82.3%)	64(17.7%)
The Community has embarked on small scale enterprise as an adaptation strategy to deal with climate variability	298(82.3%)	64(17.7%)
The Community has embarked on bead making as an adaptation strategy to deal with climate variability	291(80.4%)	91(19.6%)
The Community has embarked on livestock diversification as an adaptation strategy to deal with climate variability	298(82.3%)	64(17.7%)
The Community has embarked on risk sharing among members as an adaptation strategy to deal with climate variability	289(79.8%)	73(20.2%)

Appendix XIV: Correlations on Temperature Variations, ,

		Temperature variations on Availability of water
Temperature variations between 1989-2018	Pearson Correlation	-.188**
	Sig. (2-tailed)	.000

Appendix XV: Respondent's perception on temperature Change

STATEMENT-TEMPERATURE	No Change	Less Available	More Available
Impact of temperature variations on Availability of water	86(23.8%)	268 (74%)	8(2.2%)
Impact of temperature variations on Pasture availability	(19.1%)	293(80.9%)	
Impact of temperature variations on Milk production	219(60.5%)	95(26.2%)	48(13.3)
Impact of temperature variations on Herd Size	298(82.3%)	53(14.6%)	11(3.0%)
Impact of temperature variations on Animal Reproduction	268(74%)	86(23.8%)	8(2.2%)
Impact of temperature variations on Market Prices	293(80.9%)	69(19.1%)	0(0%)
Impact of temperature variations on Human Wildlife conflicts	261(72.1%)	86(23.8%)	15(4.1%)

Appendix XVI: Co-efficient on temperature variations

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	1.506	.126		11.985	.000
Based on your memories, and current observations, what is the state of Temperature variations between 1989-2018	-.095	.021	-.237	-4.638	.000
Based on your memories, and current observations, what is the state of Rainfall patterns between 1989-2018	.000	.030	-.001	-.011	.992
Based on your memories, and current observations, what is the state of Frequency of drought between 1989-2018	.049	.032	.079	1.498	.135
Based on your memories, and current observations, what is the state of Occurrences of floods between 1989-2018	-.065	.029	-.118	-2.205	.028

a. Dependent Variable: VMilk_Production

Correlations

		vhersize	Based on your memories, and current observations, what is the state of Temperature variations between 1989-2018	Based on your memories, and current observations, what is the state of Rainfall patterns between 1989-2018	Based on your memories, and current observations, what is the state of Occurrences of floods between 1989-2018	Based on your memories, and current observations, what is the state of Frequency of drought between 1989-2018
vhersize	Pearson Correlation	1	-.140**	.093	.153**	.082
	Sig. (2-tailed)		.008	.079	.004	.120
	N	362	362	362	362	362
Based on your memories, and current observations, what is the state of Temperature variations between	Pearson Correlation	-.140**	1	.014	-.069	.048
	Sig. (2-tailed)	.008		.786	.189	.365
	N	362	362	362	362	362

1989-2018							
Based on your memories, and current observations, what is the state of Rainfall patterns between 1989-2018	Pearson Correlation	.093	.014	1	-.177**	.035	
	Sig. (2-tailed)	.079	.786		.001	.506	
	N	362	362	362	362	362	362
Based on your memories, and current observations, what is the state of Occurrences of floods between 1989-2018	Pearson Correlation	.153**	-.069	-.177**	1	-.243**	
	Sig. (2-tailed)	.004	.189	.001		.000	
	N	362	362	362	362	362	362
Based on your memories, and current observations, what is the state of Frequen	Pearson Correlation	.082	.048	.035	-.243**	1	
	Sig. (2-tailed)	.120	.365	.506	.000		
	N	362	362	362	362	362	362

cy of
drought
between
1989-
2018

** . Correlation is significant at the 0.01 level (2-tailed).

Appendix XVII: R-model

Model Summary

Model	R	R Square	Adjusted Square	R	Std. Error of the Estimate
1	.267 ^a	.072	.061		.21821

a. Predictors: (Constant), What is the frequency of floods during 1989-2018, based on your recollections and current observations? What is the current condition of temperature fluctuations between the years 1989 and 2018, based on your recollections and present observations? According to your recollections and present observations, what is the current condition of rainfall? patterns between 1989-2018, Based on your memories, and current observations, what is the state of Frequency of drought between 1989-2018

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.309	4	.327	6.873	.000 ^b
	Residual	16.999	357	.048		
	Total	18.308	361			
a. Dependent Variable: v herd size						

b. Predictors: (Constant), According to your recollections and present observations, what is the frequency of flood events that have taken place between the years 1989 and 2018? What is the current situation of temperature fluctuations between 1989 and 2018, based on your memories and current observations? What is the current condition of rainfall patterns between the years 1989 and 2018, based on your recollections and present observations? According to your recollections and present observations, what is the frequency of drought occurrences between the years 1989 and 2018?

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.003	.097		10.368	.000
	Based on your memories, and current observations, what is the state of Temperature variations between 1989-2018	-.042	.016	-.135	-2.633	.009
	Based on your memories, and	.055	.023	.125	2.408	.017

current observations,
 what is the state of
 Rainfall patterns
 between 1989-2018

Based on your .063 .025 .132 2.509 .013

memories, and
 current observations,
 what is the state of
 Frequency of drought
 between 1989-2018

Based on your .084 .023 .198 3.699 .000

memories, and
 current observations,
 what is the state of
 Occurrences of floods
 between 1989-2018

a. Dependent Variable: v herd size

Correlations						
		Based on your memories, and current observations, what is the state of Temperature variations between 1989-2018	Based on your memories, and current observations, what is the state of Rainfall patterns between 1989-2018	Based on your memories, and current observations, what is the state of Occurrences of floods between 1989-2018	Based on your memories, and current observations, what is the state of Frequency of drought between 1989-2018	Vanimal_Reproduction
Based on your memories, and current observations, what is	Pearson Correlation	1	.014	-.069	.048	-.117*

the state of Temperature variations between 1989-2018	Sig. (2-tailed)		.786	.189	.365	.026
	N	362	362	362	362	362
Based on your memories, and current observations, what is the state of Rainfall patterns between 1989-2018	Pearson Correlation	.014	1	-.177**	.035	.045
	Sig. (2-tailed)	.786		.001	.506	.389
	N	362	362	362	362	362
Based on your memories, and current observations, what is the state of Occurrences of floods between 1989-2018	Pearson Correlation	-.069	-.177**	1	-.243**	.120*
	Sig. (2-tailed)	.189	.001		.000	.023
	N	362	362	362	362	362
Based on your memories, and current observations, what is the state of Frequency of drought between 1989-2018	Pearson Correlation	.048	.035	-.243**	1	-.072
	Sig. (2-tailed)	.365	.506	.000		.173
	N	362	362	362	362	362
Vanimal_Reproduction	Pearson Correlation	-.117*	.045	.120*	-.072	1
	Sig. (2-tailed)	.026	.389	.023	.173	
	N	362	362	362	362	362
*. Correlation is significant at the 0.05 level (2-tailed).						
**. Correlation is significant at the 0.01 level (2-tailed).						

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.180 ^a	.032	.022	.23771
<p>a. Predictors: (Constant), What is the frequency of floods during 1989-2018, based on your recollections and present observations? What is the current situation of temperature fluctuations between 1989-2018, based on your recollections and present observations? What is the current status of rainfall patterns between 1989-2018, based on your recollections and present observations? What is the frequency of drought during 1989-2018, based on your recollections and present observations?</p>				

ANOVA^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.676	4	.169	2.992	.019 ^b
	Residual	20.172	357	.057		
	Total	20.849	361			
<p>a. Dependent Variable: Vanimal_Reproduction</p> <p>b. Predictors: (Constant), What is the frequency of floods during 1989-2018, based on your recollections and present observations? What is the current condition of temperature fluctuations between the years 1989 and 2018, based on your recollections and present observations? What is the current status of rainfall patterns between 1989-2018, based on your recollections and present observations? According to your recollections and present observations, what is the frequency of drought occurrences between the years 1989 and 2018?</p>						

Coefficients ^a						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.262	.105		11.974	.000
	Based on your memories, and current observations, what is the state of Temperature variations between 1989-2018	-.036	.017	-.108	-2.072	.039
	Based on your memories, and current observations, what is the state of Rainfall patterns between 1989-2018	.032	.025	.069	1.296	.196
	Based on your memories, and current observations, what is the state of Frequency of drought between 1989-2018	-.021	.027	-.041	-.767	.444
	Based on your memories, and current observations, what is the state of Occurrences of floods between 1989-2018	.052	.025	.114	2.096	.037
a. Dependent Variable: V animal Reproduction						

Correlations						
		Based on your memories, and current observations, what is the state of Temperature variations between 1989-2018	Based on your memories, and current observations, what is the state of Rainfall patterns between 1989-2018	Based on your memories, and current observations, what is the state of Occurrences of floods between 1989-2018	Based on your memories, and current observations, what is the state of Frequency of drought between 1989-2018	Vmarket_Prices
Based on your memories, and current observations, what is the state	Pearson Correlation	1	.014	-.069	.048	-.177**
	Sig. (2-tailed)		.786	.189	.365	.001

of Temperature variations between 1989-2018	N	362	362	362	362	362
Based on your memories, and current observations, what is the state of Rainfall patterns between 1989-2018	Pearson Correlation	.014	1	-.177**	.035	.102
	Sig. (2-tailed)	.786		.001	.506	.052
	N	362	362	362	362	362
Based on your memories, and current observations, what is the state of Occurrences of floods between 1989-2018	Pearson Correlation	-.069	-.177**	1	-.243**	.082
	Sig. (2-tailed)	.189	.001		.000	.122
	N	362	362	362	362	362
Based on your memories, and current observations, what is the state of Frequency of drought between 1989-2018	Pearson Correlation	.048	.035	-.243**	1	-.109*
	Sig. (2-tailed)	.365	.506	.000		.038
	N	362	362	362	362	362
Vmarket_Prices	Pearson Correlation	-.177**	.102	.082	-.109*	1
	Sig. (2-tailed)	.001	.052	.122	.038	
	N	362	362	362	362	362
**. Correlation is significant at the 0.01 level (2-tailed).						
*. Correlation is significant at the 0.05 level (2-tailed).						

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate

1	.240 ^a	.057	.047	.24598
a. Predictors: (Constant), According to your recollections and present observations, what is the frequency of flood events that occurred between 1989 and 2018? What is the extent of temperature fluctuations between 1989 and 2018, as determined by your recollections and present-day observations? According to your recollections and present observations, what is the status of precipitation patterns from 1989 to 2018? What is the frequency of drought from 1989-2018, based on your recollections and current observations?				

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.316	4	.329	5.439	.000 ^b
	Residual	21.601	357	.061		
	Total	22.917	361			
a. Dependent Variable: Vmarket_Prices						
b. Predictors: (Constant), What is the frequency of floods during 1989-2018, based on your recollections and present observations? What is the current condition of temperature fluctuations between the years 1989 and 2018, based on your recollections and present observations? According to your recollections and present observations, what is the status of precipitation patterns from 1989 to 2018? According to your recollections and present assessments, what is the frequency frequent drought occurrences between the years 1989 and 2018?						

Coefficients ^a						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.389	.109		12.737	.000
	Based on your memories, and current observations, what is the state of Temperature variations between 1989-2018	-.059	.018	-.169	-3.284	.001
	Based on your memories, and current observations, what is the state of Rainfall patterns between 1989-2018	.059	.026	.120	2.299	.022

	Based on your memories, and current observations, what is the state of Frequency of drought between 1989-2018	-.047	.028	-.088	-1.666	.097
	Based on your memories, and current observations, what is the state of Occurrences of floods between 1989-2018	.033	.025	.070	1.291	.197
a. Dependent Variable: Vmarket_Prices						

Correlations						
		Based on your memories, and current observations, what is the state of Temperature variations between 1989-2018	Based on your memories, and current observations, what is the state of Rainfall patterns between 1989-2018	Based on your memories, and current observations, what is the state of Occurrences of floods between 1989-2018	Based on your memories, and current observations, what is the state of Frequency of drought between 1989-2018	Livestock diseases
Based on your memories, and current observations, what is the state of Temperature variations between 1989-2018	Pearson Correlation	1	.014	-.069	.048	-.065
	Sig. (2-tailed)		.786	.189	.365	.217
	N	362	362	362	362	362
Based on your memories, and current observations, what is the state of Rainfall patterns between 1989-2018	Pearson Correlation	.014	1	-.177**	.035	-.114*
	Sig. (2-tailed)	.786		.001	.506	.031
	N	362	362	362	362	362
Based on your memories, and current observations, what is the state of Occurrences of floods between 1989-2018	Pearson Correlation	-.069	-.177**	1	-.243**	.208**
	Sig. (2-tailed)	.189	.001		.000	.000
	N	362	362	362	362	362

Based on your memories, and current observations, what is the state of Frequency of drought between 1989-2018	Pearson Correlation	.048	.035	-.243**	1	-.104*
	Sig. (2-tailed)	.365	.506	.000		.049
	N	362	362	362	362	362
Livestock diseases	Pearson Correlation	-.065	-.114*	.208**	-.104*	1
	Sig. (2-tailed)	.217	.031	.000	.049	
	N	362	362	362	362	362
**. Correlation is significant at the 0.01 level (2-tailed).						
*. Correlation is significant at the 0.05 level (2-tailed).						

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.234 ^a	.055	.044	.25333
a. Predictors: (Constant), What was the occurrence rate of floods during the period from 1989 to 2018, as per your personal memories and recent observations? How would you describe the degree of temperature variations between 1989 and 2018, based on your personal recollections and present-day observations? In your opinion, what are the current precipitation patterns between the years 1989 and 2018, as influenced by your own recollections and current observations? From your perspective, how often did droughts happen from 1989 to 2018, as per your personal memories and present-day observations?				

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.329	4	.332	5.176	.000 ^b
	Residual	22.911	357	.064		
	Total	24.240	361			
a. Dependent Variable: Livestock diseases						

b. Predictors: (Constant), According to your recollections and current observations, what is the status of flood occurrences during the period from 1989 to 2018? Based on your personal memories and present-day observations, how would you characterize the extent of temperature fluctuations between 1989 and 2018? In your view, what is the current condition of rainfall patterns between the years 1989 and 2018, as influenced by your own recollections and present-day observations? From your perspective, how often did droughts occur from 1989 to 2018, based on your personal memories and present-day observations?

Appendix XVIII: Respondent’s perception on Frequency of drought

STATEMENT-DROUGHT	No Change	Less Available	More Available
Impact of frequency of droughts variations on Availability of water	235(64.9%)	88(24.3%)	39(10.8%)
Impact of frequency of droughts variations on Availability of water			
Impact of frequency of droughts on Pasture availability	293(80.9%)	62(17.1%)	7(1.9%)
Impact of frequency of droughts on Milk production	256(70.7%)	84(23.2%)	22(6.1%)
Impact of frequency of droughts on Herd Size	280(77.3%)	77(21.3%)	5(1.4%)
Impact of frequency of droughts on Animal Reproduction	271(74.9%)	91(25.1%)	0(0.0%)
Impact of frequency of droughts on Market Prices	305(84.3%)	57(12.7%)	0(0.0%)
Impact of frequency of droughts on Human Wildlife conflicts	253(69.9%)	80(22.1%)	29(8.0%)

Model Summary				
Model	R	R Square	Adjusted Square	Std. Error of the Estimate
1	.223 ^a	.050	.034	.19660

Predictors: (Constant), The government has established a plan of raising knowledge of climate variability indicators as a means of adapting to and addressing climate variability. As an adaptation technique to address climatic variability, the government has implemented land demarcation.

Are you a Pastoralist?

		Frequency	Percent	Valid %	Cumulative Percent
Valid	YES	323	89.2	89.2	89.2
	NO	37	10.2	10.2	99.4
	3	2	.6	.6	100.0
	Total	362	100.0	100.0	

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.719	6	.120	3.102	.006 ^b
	Residual	13.721	355	.039		
	Total	14.440	361			

a. Dependent Variable: RG Vulnerability

	N	Std. Deviation	Mean	Maximum
Number of household members	362	3.771	9.03	17

How many years have you lived in this region

		Frequency	Percent
Valid	0-5 YEARS	55	15.2
	6-10 YEARS	59	16.3
	11-15 YEARS	100	27.6
	16-20 YEARS	56	15.5
	Over 20years	56	15.5
	6	36	9.9
	Total	362	100.0

Period Class Type	(1988-1998) - (1998-2008)		(1998-2008) – (2008-2018)	
	(ha)	(%)	(ha)	(%)
Thick Vegetation	-138417.48	-28.45	-2992.95	-0.62
Vegetation	-19669.14	-4.04	-115042.59	-23.65
Rangelands	135004.86	27.75	-12782.88	-2.62
Bare land	8022.51	1.65	116360.01	23.91

Number of years practicing Pastoralism

	N	Std. Deviation	Mean	Maximum
How many years of Pastoralism do you have	362	5.082	13.22	24
Valid (listwise)	N 362			