IMPACTS OF CLIMATE CHANGE, HOUSEHOLD VULNERABILITY AND ADAPTATION STRATEGIES AMONG THE GABBRA PASTORALISTS IN MARSABIT COUNTY, KENYA

BY

MAMO BORU MAMO (BSc., MSc.)
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DECLARATION

I, the undersigned, declare that this is my original work and has not been submitted to any other college, institution or university other than Kenyatta University for academic credit.

Signed…………………………….

Date: …………………………..

Mamo Boru Mamo

Reg. No.: N85/28922/2013

Department of Environmental Science and Education

School of Agriculture and Environmental Sciences

Kenyatta University

Declaration by Supervisors

We confirm that the work reported in this thesis was carried out by the candidate under our supervision.

Signature: ………………………... Date: ………………………………

Dr. John Muriuki

Department of Environmental Science and Education

School of Agriculture and Environmental Sciences

Kenyatta University

Signature: …………………… Date: …………………………

Dr. Ezekiel Ndunda

Department of Environmental Science and Education

School of Agriculture and Environmental Sciences

Kenyatta University

DEDICATION

I am dedicating this thesis to my lovely wife Kame and our dear children: Ibrae, Adho, Sarah and Isaack. You are the best gift in my life and a great source of inspiration. May Almighty God bless you.

To the great people, the Gabbra Community, of Northern Kenya I salute you for your resilience to climate change and adaptive capacity to climate variability. May your adaptation and mitigation measures always be timely to address the changing climate.

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ABBREVIATIONS AND ACRONYMS

AR	Autoregressive component
ASALs	Arid and Semi-Arid Lands
AU	African Union
EIWEN	Endorois Indigenous Women Empowerment Network.
FAO	Food and Agriculture Organization
IGAD	Intergovernmental Authority on Development
IDA	International Disability Alliance
IPCC	Intergovernmental Panel on Climate Change
HED	International Institute for Environment and Development
IISD	International Institute for Sustainable Development
IPWDGN	Indigenous People With Disabilities Global Network
KMD	Kenya Meteorological Department
KNBS	Kenya National Bureau of Statistics
LVI	Livelihood Vulnerability Index
MK	Mann-Kendall
NGOs	Non-Governmental Organizations
SDG	Sustainable Development Goal
WFP	World Food Programme
WMO	World Meteorological Organization

DEFINITION OF TERMS

Adaptation: Process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities.

Adaptive capacity: Ability to adjust to changing climate conditions, including extreme weather events, by taking advantage of opportunities, mitigating potential damage and coping with the consequences.

Adaptive strategies: Long-term strategies that allow people to respond to a new set of evolving conditions that they have not previously experienced.

Arid and semi-arid lands: Geographical areas that receive little rainfall with arid being areas receiving least amount of precipitation while semi-arid receives slightly more.

Climate change: Change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer.

Climate resilience: Ability of a community or system to prepare for, withstand and recover from effects of climate change.

Climate risk: Potential harm to the environment, society and economy caused by climate change.

Climate variability: Variations in the mean state and other statistics of the climate at all spatial and temporal scales beyond that of individual weather events.

Exposure: Presence (location) of people, livelihoods, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be affected adversely by physical events resulting into future harm, loss, or damage.

Extreme events: Facet of climate variability leading into occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends („tails") of the range of observed values of the variable.

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

Rangeland: Land on which the native vegetation, predominantly grasses, grass-like plants, forbs, or shrubs are suitable for grazing or browsing use.

Sensitivity to climate change: Degree to which people or an ecological system are affected by sudden and extreme weather events caused by climate change.

Sustainable resilience: Ability to adapt and thrive in the face of change while also meeting the needs of the present and future.

Vulnerability to climate change: Degree to which a household is unable to cope with the adverse effects of climate change.

ABSTRACT

The livelihoods of pastoralist communities in Kenya are largely climate sensitive due to their dependence on natural resources. Ecological and socioeconomic conditions of rangeland areas occupied by pastoral communities most probably contribute to an increase in their vulnerability due to the impacts brought about by climate change. Few studies have looked into this particular aspect in relation to the northern rangelands. This study was carried out in Marsabit County of Kenya with overall objective of assessing Gabbra pastoralists' perceptions, impacts, vulnerability, and adaptation strategies against climate change. Specifically, the study sought to:- assess the extent of climate change by analyzing trends in temperature and precipitation; evaluate the local community perception and impacts of the changing climate; identify the adaptation strategies adopted by Gabbra community; and determine the vulnerability of Gabbra community households to climate change. The study adopted a mixed research design. Mann–Kendall test and Theil-Sen’s slope estimator to analyze monthly, seasonal and annual temperature and precipitation trends for Marsabit County from 1990 to 2022. Data was also collected from 398 randomly selected pastoralists from the Gabbra community using household interviews, observations, and discussions including a Likert-scale to assess Gabbra pastoralists perceptions on climate change, impacts and adaptations they undertake. The study also assessed the livelihood vulnerability of Gabbra pastoralists who depend on livestock, crops and natural resources for their livelihood. The degree of livelihood vulnerability between the different sub-counties, livelihood vulnerability index was used. Results revealed decreasing, but non-significant, trends in the monthly, seasonal and annual precipitation. When the monthly, seasonal and annual data for maximum and minimum temperature was evaluated, the results revealed an upward and statistically significant ($p \leq 0.05$) trend. The results further showed that Gabbra pastoralists have been perceiving climate through disruptions of their normal socio-economic activities and lifestyles, largely occasioned by climatic parameters, especially rainfall. Climate impacts were largely attributed to rainfall and temperature variations. Gabbra pastoralists have adaptation strategies that largely focus on livestock, crop and soil management. Composite method results, showed high vulnerability to climate change among the Gabbra. Similar results were obtained using livelihood vulnerability index-intergovernmental panel on climate change indicating that the community has low adaptive capacity, while highly sensitive and exposed to the shocks of climate change. Multivariate Probit regression model showed that gender, age, education, monthly income, household size, membership to social group, increasing temperature, unpredictable rainfall patterns, increased drought frequency, assistance from government, assistance from relatives, access to extension services, access to credit services, water availability, pasture availability, and own large herd of livestock as statistically significant ($p \leq 0.05$) determinants in choosing adaptation strategies in the face of climate change. The study concludes that rainfall has been progressively decreasing while temperatures have gradually risen from 1990 to 2022. Gabbra pastoralists have perceived climate change through climatic variations experienced and consequential disruptions of socioeconomic activities and livelihoods. The community has adopted various strategies to address impacts of climate change that involve aspects of livestock, crop and soil management. Further, they were found to be highly vulnerable to climate change. The study recommends development of nature-based interventions such as ecosystems restoration, management of biodiversity, water and soils, which deliberately incorporates indigenous knowledge. Climate adaptation strategies that minimize households’ degree of sensitivity and enhance their adaptive capacity should be promoted. In adaptation there is a need to seek increased adoption of climate-smart technologies for use by the Gabbra community.

CHAPTER ONE
INTRODUCTION

1.1 Background to the Study

Climate change is presently posing a major environmental challenge and is negatively impacting Africa (Adger *et al*., 2004; WMO 2019) with temperature increase above 1.5°C, posing grave consequences on sustainable development (IPCC 2018). According to the African Union (2023), climate change is currently being considered as an existential threat to Africa's communities, ecosystems and economies. Underlying this change are human influences on the physical elements of climate (Maycock *et al*., 2021). Projections by IPCC, 2012, indicate that Africa's climate may become warmer and drier in future and with high possibilities of more intense variabilities that may give rise to droughts, heatwaves, violent storms, cyclones and floods among other extreme climatic events. Further, the continent is also projected to bear an increasing proportion of the total global exposed and vulnerable populations (IPCC, 2018). Climate change is accompanied by impacts that have far reaching effects on biodiversity, landscapes, people and their socio-economic structures.

Pastoral economy in Africa is largely concentrated in arid and semi-arid landscapes and where water scarcity is of regular occurrence and mainly involves keeping large herds of cattle, sheep, goats, camels and donkeys. Climate change in these areas largely manifests itself in the form of drought occasioned by reduced precipitation or flooding due to heavy rains. To protect their economy and livelihoods the pastoralists more often undertake adaptations to overcome resultant impacts which are largely conditioned by landscape conditions, including population sizes, tenure and culture. Mobility, commonly known as transhumance and which has evolved over years and part of pastoral communities' way of life and is critical to securing water and pastures for their livestock. Being mobile allows the nomadic pastoralists to take advantage of new water sources available in rainfall pools, filled up water pans, seasonal streams and rivers and occasional swamps before they dry up. They are also able to utilize new grass and other fodder available in these 'new and less productive or marginal landscapes (Nkuba *et al*., 2019) on time before another period of drought commences. Indigenous knowledge is critical in these mobility efforts.

In East Africa, and Kenya in particular, population dynamics both in terms of increased number of people in ASAL areas as well as livestock numbers result in pronounced landscape changes and especially in vegetational or plant cover changes which are evidently visible. The natural biodiversity resources in these areas are very crucial since people, biodiversity and climate change and ASALS economies are highly interdependent (Lutta, *et al* 2024). The rangelands of Kenya and whose land tenure have for years been largely communal have in recent decades seen privatization take root, with many areas being subdivided and fenced off to the detriment of nomadic pastoral life as previously available lands and movement routes gradually diminish. This is further compounded by sedentarization of pastoral communities which in recent years have become a common feature. For many years most of ASAL pastoral areas have operated as communal or community lands or clan lands designated as group ranches.

Understanding local communities' perspectives on climate change is becoming increasingly important as its effects on landscapes and socioeconomics continue to reverberate. Perception about climate change and its impacts among communities affects the incentive to adopt adaptive action, is therefore an important for consideration. Climate change is a phenomenon where different attributes of weather and especially rainfall and temperatures change unpredictably and the magnitude of change create effects that are spread across all entities of the environment, including social systems. Pastoral communities faced with impacts that arise from climatic change and variability of its components often adopt both similar and differing perceptions on the phenomena, but which are important in determining actions to take. An understanding of these perceptions is crucial in guiding decision making and for adaptation planning efforts (Fosu-Mensah *et al*., 2012).

Pastoralists in ASALs of Kenya are dependent on ecological services thus making them highly dependent on the rainfall and temperature patterns (Mahmood *et al*., 2021; Shah *et al*., 2020). Therefore, the livelihood of pastoral communities is an integral part of climate change induced vulnerability and risk. However, there has been limited research on livelihood security despite the challenges posed by climate variability and change (Blackmore *et al*., 2021). Marsabit County has been experiencing increased variability, intensity and frequency of climate variability and change (Gudere *et al*., 2022). This has adversely affected the livelihoods, local economies, cultural assets, public health and wellbeing, environmental assets and ecosystem services (IPCC, 2021). Therefore, there was a need in this study to also assess the livelihood vulnerabilities of -pastoral communities in Marsabit County. This was found to be important in understanding the susceptibility of pastoralist communities to climate change induced disasters, and in guiding development of interventions, strategies and policies to enhance livelihoods of the -pastoralist in Marsabit County.

In Kenya about three quarters of land is arid and semi-arid and is occupied by ethnic communities with differing cultures and are mostly engaged in pastoralism. Pastoralism as an economic as well as a social engagement has many similarities as well as differences in the way it is practiced among different communities. The level and magnitude of pastoral practices among Kenya pastoral communities was noted to be highly variable and conditioned by prevailing landscape ecosystems, climate, water availability, history, cultures and associated perceptions. The Gabbra community mainly occupy the central areas of the Northern rangelands and can be regarded as a pure pastoral community. The implications of climate change and variability, its impacts, and adaptations and vulnerability factors among Gabbra pastoralists in Kenya's Marsabit County were the specific focus of this study.

1.2 Statement of the Problem

The problem statement that guided this study was the existing and emerging common in ASAL areas, and specifically those of Marsabit County located in the northern ranges of Kenya. Determination of rainfall and temperature trends in Marsabit county have been inadequate yet this is important in tracking existence and extent of climate change. Perceptions and adaptations of Gabbra pastoralists in the Northern Rangelands to the unpredictable nature of climate change are poorly understood (Van Duijne *et al*., 2024). Recently, long-lasting droughts that frequently end in extremely heavy, brief rains that resulted in widespread flooding have put Gabbra communities, their livestock herds, and the ecosystems they inhabit in Kenya's northern rangelands have been at risk due to climate variability and change.

Prolonged droughts and intense flooding both lead to massive livestock losses in areas occupied by Gabbra communities and have become more common and irregular with time, particularly in Marsabit County, where this research was carried out (Ong'eta, 2021). The lack of a wide range of variety of sources for household incomes, weak sociocultural capital and inadequacies in governance possibilities have been major factors for the increased susceptibility of Gabbra populations. Additionally, the community face limited livestock marketing opportunities and is continuously experiencing internal changes in land tenure; unclear property rights regimes, occasional inter-tribal conflicts, as well as changes in traditional social institutions and resource allocation systems (Otieno *et al*., 2024).

There have also been pronounced instances of gender inequity and exclusions and particularly marginalization of women coupled with a low human resource capacity to manage changes among other factors. There exists an acute scarcity of documented evidence of large-scale livestock losses in Marsabit County during various droughts or floods periods; and similarly, on Gabbra adaptation and coping efforts and also on factors collectively undermining pastoral community's sustainability and resilience in the face of otherwise "normal" climatic variability. Establishing specific factors for climate change influenced pastoralism livelihood outcomes is crucial. While Gabbra pastoralists have long used indigenous methods to cope with shock and stress caused by harsh environmental conditions, the increasing climatic variability and associated a high regularity of extreme weather events is introducing new dimensions or challenges that in turn become limiting factors to adaptation, coping strategies and also to resilience.

1.3 Research Questions

The research questions for the study were:

1) How have been the trends in temperature and precipitation between 1990 and 2022 in Marsabit County?

2) How do Gabbra Pastoralists in Marsabit County perceive the impacts of climate change?
3) What are the key adaptation strategies by the Gabbra Pastoralists in Marsabit County?
4) Why are the Gabbra Pastoralists in Marsabit County vulnerable to climate change?

1.4 Objectives of the Study

1.4.1 Overall Objective

The overall objective of this study was to assess the trends of precipitation and temperature to climate change, perceptions about the impacts of climate change, adaptation strategies to climate change and household vulnerability to climate change in Marsabit County.

1.4.2 Specific Objectives

The specific objectives of this research were as follows:

1) To examine temperature and precipitation trends in Marsabit County between 1990 and 2022.
2) To assess Gabbra pastoralists' perception about the impacts of climate change on livelihoods in Marsabit County.
3) To examine the factors that influence Gabbra pastoralists' decision-making on their adaptation tactics in Marsabit County as a result of climate change.
4) To evaluate household vulnerability of Gabbra pastoralists to climate change in Marsabit County.

1.5 Research Hypotheses

The following hypotheses guided the research:

1) There is a statistically significant trend for temperature and precipitation trends in Marsabit County between 1990 and 2022.
2) Adaptation strategies to climate change that are undertaken by Gabbra pastoralists are significantly influenced by socioeconomic, institutional and ecological factors.

3) Gabbra households in Marsabit County are significantly vulnerable to climate change.

1.6 Justification of the Study

The study on the impacts of climate change, household vulnerability, and adaptation strategies among the Gabbra pastoralists in Marsabit County, Kenya, is justified by several critical factors that highlight its relevance and importance.

1. Climate Change as a Global Challenge: Climate change is a pressing global issue with far-reaching impacts on ecosystems, economies, and livelihoods. Africa, and Kenya in particular, is highly vulnerable to climate change due to its dependence on climate-sensitive sectors such as agriculture and pastoralism. The Gabbra pastoralists, who rely heavily on natural resources for their livelihoods, are particularly susceptible to the adverse effects of climate variability and change. Understanding how these communities perceive, adapt to, and are impacted by climate change is crucial for developing effective mitigation and adaptation strategies.
2. Limited Research on Northern Rangelands: While there is a growing body of literature on climate change impacts and adaptation strategies, there is a notable gap in research focusing on the northern rangelands of Kenya, particularly among the Gabbra pastoralists. This study aims to fill this gap by providing a detailed analysis of climate trends, perceptions, and adaptation strategies specific to this region. The findings will contribute to the broader understanding of climate change impacts on pastoral communities in arid and semi-arid lands (ASALs).
3. Vulnerability of Pastoral Communities: Pastoral communities, such as the Gabbra, are among the most vulnerable to climate change due to their reliance on livestock and natural resources. The increasing frequency and intensity of droughts, floods, and other extreme weather events have exacerbated their vulnerability, leading to significant livestock losses, food insecurity, and economic hardship. This study seeks to assess the extent of this vulnerability and identify the factors that influence the adaptive capacity of these communities.
4. Indigenous Knowledge and Adaptation Strategies: The Gabbra pastoralists have developed various indigenous adaptation strategies over generations to cope with climate variability. However, the effectiveness of these strategies is increasingly being

challenged by the unprecedented pace of climate change. This study aims to document and evaluate these traditional adaptation practices, providing insights into how they can be integrated with modern climate-smart technologies to enhance resilience.

5. Policy and Development Implications: The findings of this study will have significant implications for policy formulation and development planning in Marsabit County and other ASAL regions. By identifying the key drivers of vulnerability and the most effective adaptation strategies, the study will provide valuable information for policymakers, development practitioners, and local communities. This will enable the design of targeted interventions that enhance the adaptive capacity of pastoral communities and promote sustainable livelihoods.
6. Contribution to Sustainable Development Goals (SDGs): The study aligns with several Sustainable Development Goals (SDGs), particularly SDG 1 (No Poverty), SDG 2 (Zero Hunger), and SDG 13 (Climate Action). By addressing the impacts of climate change on pastoral livelihoods and identifying strategies to enhance resilience, the study contributes to the global efforts to achieve these goals.

1.7 Significance of the Study

Much of the existing literature on vulnerability studies has greatly concentrated on theoretical insights or analysis at regional or national scales, with findings for each case having greater implications for system-wide planning (Hinkel, 2011). In Kenya's ASALs, there is still much ambiguity and a scarcity of scientific information including that of in-depth analysis of communities and household's vulnerability occasioned by climate variability and change and consequential adaptation strategies (Kalele *et al*., 2021).

One major aspect within the goal of this research was to provide additional insight into the scientific understanding needed to support families' and communities' adaptation plans and coping mechanisms in the face of growing climatic unpredictability and change in ASALs. The study outcomes provide insights into the ways in which Gabbra socioeconomic lives are impacted by climate change, specifically in terms of the degrees of susceptibility. The study also contributes to understanding Gabbra pastoralists adaptation strategies on ecological and socioeconomic activities in response to climate change, bringing forth new findings or knowledge; and information that can guide future research and actions. The study has generated additional data that can be used to guide policy review or change, including new aspects of climate change-pastoralist paradigms that may lead to additional research.

1.8 Conceptual Framework

The conceptual framework that guided this study was based on ecological theory (Gibson, 1979), which states that, "organisms and their environments are inseparable and have interactions that cannot be defined independently of one another". As a result, for successful adaptation (and which develops in relation to environmental factors associated with an organism's survival), perception of which aspects of surface, substance, and medium strive to persist but which may change in response to specific environmental events is required. Two principles guide ecological perception theory: (i) animal-environment systems and (ii) guiding activity for adapting to the presented environment. As a result, the perceiver's environment influences how they behave within that environment. In this regard, perception is critical because it allows humans to adapt (condition their daily activities) to meet the challenges brought about by environmental changes or phenomenal events such as climate change.

Climate change, according to the conceptual framework has an impact on pastoral communities' livelihood systems, which include economic factors (income, large number of livestock), socio-cultural factors (communal life, including resource sharing, cultural activities centred on clans, households, families, and polygamy, among others), health and nutrition factors (feeding habits, nutrition), and environmental factors (ecosystem change and especially grassland and associated fodder, water access and availability). The conceptual framework presented in Figure 1.1 facilitates an analysis of the potential correlation between the phenomena of climate change and pastoralists' perceptions of it, as well as the strategies they employ to cope with disruptions to their livelihoods and maintain their resilience. Climate change is a reality, and its effects are felt on a global scale at various scales or magnitudes. Pastoralism is both an economic lifeline and a culture among the Gabbra in northern Kenya, and the environmental implications are directly visible through prolonged droughts, acute water scarcity, and pasture deterioration, among other things. Similarly, climate manifests itself in the region as short, intense, or heavy rainfall, causing severe flooding and livestock loss. Gabbra pastoralists must therefore concentrate on protecting livestock from losses caused by water scarcity during droughts or flooding. Climate change is changing livelihood patterns, which are influenced by perceptions and adaptations implemented.

Climate change will undoubtedly disrupt the 'traditional Gabbra livestock production' system. The framework demonstrates that adaptation strategies can also influence livelihoods, such as being able to access water even when there is no rain, whether through water storage or digging wells, or engaging in environmental conservation or food diversification - all of which reflect changes in livelihoods. The conceptual framework was utilized in this study to comprehend the adaptation tactics adopted by Gabbra pastoralists in Marsabit County. The concept explains the broad linkages in which interacting ecological, socioeconomic, and institutional pressures essentially initiate the vulnerability of the pastoral system. Pastoral households also modify their coping and adaptation mechanisms; however, state-led external interventions, such as land tenure structures and pastoral development policies, limit their capacity to react to climate variability and change.

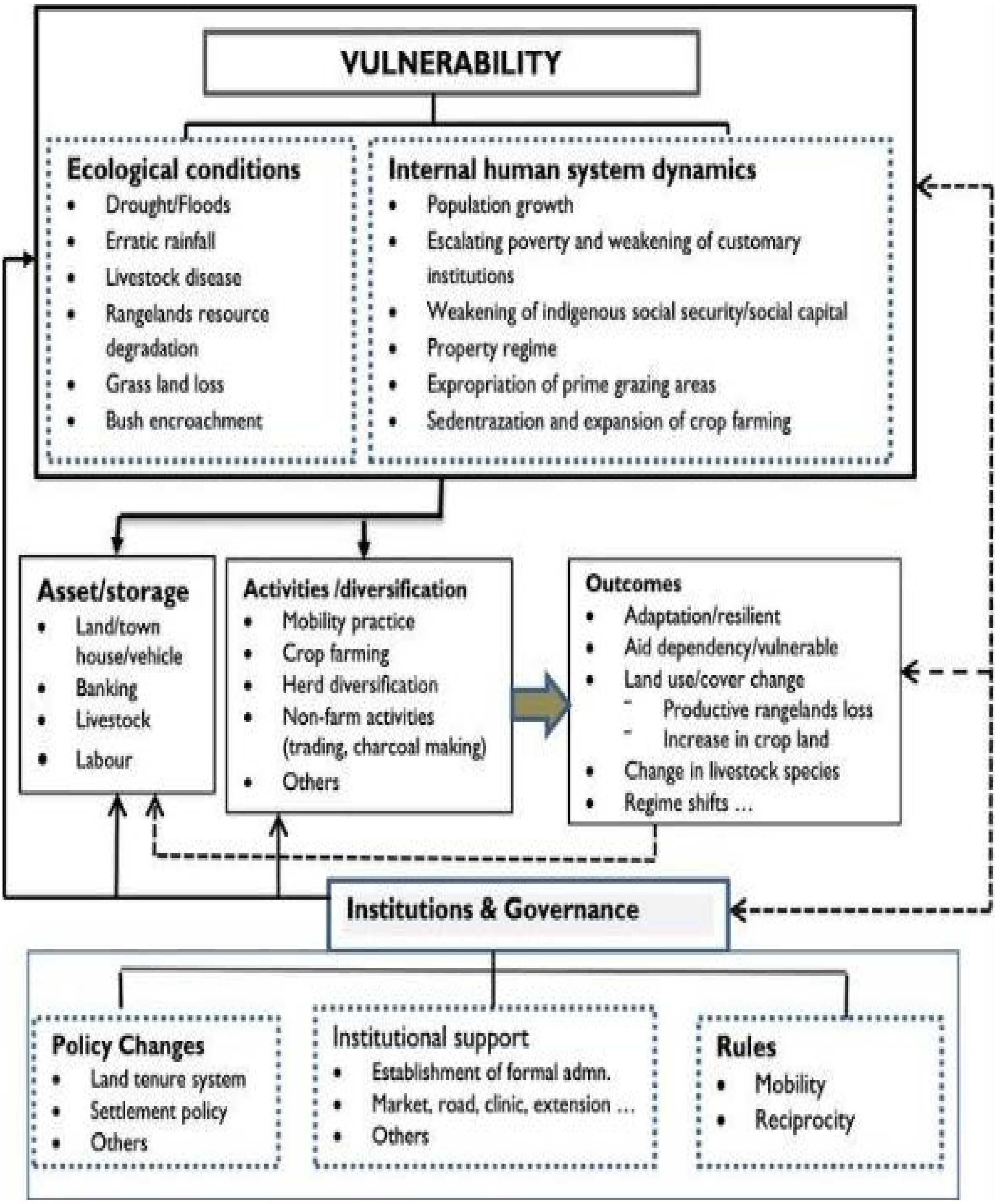

Figure 1.1. Conceptual framework showing the impacts of climate change and adaptation strategies among the Gabbra pastoralists of Marsabit County, Kenya

Source: Adapted from Tolera & Senbeta (2020), Tango International (2013) and Ellis (2000).

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

This chapter presents literature that supports this study and starts with an overview of establishing how changes rainfall and temperature patterns have been used as key indicators of a changing climate. The views of different scholars on the subject of climate change impacts and adaptations drawing lessons from Gabbra pastoralists of the Northern rangelands of Kenya. In-depth knowledge on management of pastoralism-based livelihoods including success factors and challenges posed by climate change and associated vulnerabilities is key to understanding adaptation practices undertaken by any specified community group.

The factors of sustenance and resilience allow for continuity of the adaptation activities and community lifestyles. Studying adaptation practices to climate change impacts at the local level contributes a lot in safeguarding measures that are undertaken and including rescue efforts such as re-stocking in situations where climatic impacts extensively on pastoralist community livelihood base. Climate variability and change have significant implications on biodiversity and especially on species and ecosystems; and also, on the biophysical and socio-cultural dimensions of the environment. The resultant change impacts have had outcomes of deprivation in grassland ecosystems which form the main nutritional base that support livestock populations. Kenya is one of the Horn of Africa countries; a region where drought related vulnerability is on the rise as a result of climate variability and change and associated factors including high poverty levels, violent conflicts among pastoral communities thus providing compelling justification for continuous and effective adaptation strategies (Smit and Pliskova, 2003).

2.2 Climate change phenomenon in relation to arid and semi-arid lands

Global Climate change has been on the rise owing largely to anthropogenic greenhouse gas emissions (IPCC, 2007). In earlier years and for most parts of the world, drought and rainfall events were regular and characterized by relatively predictable seasons even in arid and semi-arid pasture land areas, a situation which has changed in recent years and attributable to climate variability and change. Climate change is widely acknowledged to be on the rise owing largely to anthropogenic greenhouse gas emissions thus creating intense national and international concerns. The global average temperature has risen by 0.76 degrees Celsius over the last 150 years, with 11 of the last 12 years (1995-2006) ranking among the 12 warmest since 1850 (IPCC, 2007). According to climate studies by the Intergovernmental Panel on Climate Change IPCC (2012), the unpredictability of climate in recent years would require that appropriate measures and strategies that are critical for mitigating their resultant effects be undertaken.

Arid and semi-arid regions, in particular, frequently experience problems brought about by changes in climate, a situation that almost always ends in significant negative implications for these areas' water resources (Sivakumar et al., 2005); production systems and livelihoods. Hydrological processes are further impacted by reductions in moisture availability due to changes in precipitation, evaporation, infiltration, runoff and loss of vegetation cover. Semi-arid lands in recent years have also wetter patches of land that are at times used for crop farming thus denying pastoralists refuge for grazing during dry seasons. Other areas have also been sealed off either as private pastures or having been converted into wildlife conservation areas. Such scenarios have serious consequences for the nearly 40% of the world's population who live in dryland areas in terms of water use, management, and livelihoods (IISD, 2003). According to the Intergovernmental Panel on Climate Change (IPCC, 2012), it is hypothesized that climate change will cause significant reductions in water resources for nearly three billion more people by the year 2080 (McCarthy, 2010).

2.3 Rainfall and temperature trends

Climate data are essential in an array of climate research and applications (Dinku, 2019) and data from studies on climate change have demonstrated how the availability of meteorological data may affect people's opinions and actions. The analysis of long-term changes in climatic variables is a fundamental task in studies on climate change detection (Panda and Sahu, 2019). In any one given land locality, climate change is associated with long-term changes in various climatic elements. In arid and semi-arid areas variability in the patterns of occurrence and intensity levels of the two parameters, namely rainfall or temperature represent key indicators of change and directly or indirectly impact on landscape characteristics ecosystems and community livelihoods. Increased precipitation can replenish water supplies while low levels of precipitation may lead to drought situations and consequently water scarcity over land. In most cases, increase in the temperature of the atmosphere, oceans and over land masses is associated with global precipitation levels experienced. Increased heating leads to greater evaporation and thus surface drying, thereby increasing intensity and duration of drought (Trenberth, 2011). The changes in temperatures whether high or low have impacts on ecosystems, agriculture and health among others. In arid and semi-arid areas, the combined effect of both rainfall and temperature variations in most cases serve to determine the severity levels of climatic changes experienced, and consequently the practices and performance in pastoralism.

A number of authors (Gebrechorkos et al 2019; Panda and Sahu, 2019; Kew et al 2024) have investigated the influence of increasing temperatures and precipitation deficits, based on recognition that temperature and rainfall trends are important indicators of climate change. IPCC (2014), recognized the existence of irresistible scientific evidence on increasing temperature and the devastating effect of climate change related to it on diverse sections of the economy. Interrogating past temperature and precipitation variability at different timescales is pivotal in understanding how these climatic variables impact socio-economic sectors (Libanda *et al*., 2020) According to IPCC, 2014) of great concern are the climate change and variation impacts on agriculture, water resources, human wellbeing, ecosystem and biodiversity (IPCC, 2014).

Long-term rainfall and temperature data are crucial for understanding climate variability, forecasting future scenarios, and enabling policy development. In the light of this, the Intergovernmental Panel on Climate Change (IPCC) has noted the urgent need for global cooperation to implement climate action plans to mitigate the impacts of climate change (IPCC, 1923). As such there is great need for accurate and timely weather and climate information for planning proactive measures to mitigate and build resilience, by promoting sustainable practices in agriculture, water management, and urban planning to reduce and prevent rainfall and temperature extremes from becoming disasters and threats to livelihood in the study location (Ishaku, et al 2024). Greater efforts towards accelerating actions for adapting to climate change and the need to close the gap between existing adaptation and what is needed (IPCC 2023). A starting point being the assessment of temperature and rainfall trends and patterns for specified periods of time of target areas in order to determine both short term climatic variations and long-term climatic change.

2.4 Pastoral Communities in Kenya

Pastoralism is the most efficient way of using resources in dryland and marginal areas making pastoralism-based occupations better than those of settled farmers (Kandagor, 2005). Pastoralism is a livelihood system that enables dry land people to cope with climatic variations of dry land areas. While there are many communities in Kenya whose economic mainstay is livestock keeping, pure pastoral communities of Kenya are the Maasai, Samburu, Rendile, Gabbra, Borana,Turkana and Pokot. Others include pastoralists in the Northern, North Eastern and South Eastern rangelands of Kenya namely, Orma and the Somali sub-tribes.

The practice of pastoralism by these communities (and many other smaller communities) is either on semi-nomadic or full-time basis depending on prevailing climatic conditions, pastureland, water availability with cultural perceptions on livestock-based livelihoods being a key determinant of their movements. Productivity of pastoralism-based economy is highly variable for any given year depending largely on prevailing climatic conditions which determine pasture conditions and water availability. In some instances, localized conflicts are witnessed among the pastoralists and especially during dry spells when key pasture resources become scarce and competition intense. In Marsabit three primary types of conflicts that have been experienced in the recent past have been identified as natural resources-based, ethno-political, and those that are culturally driven (International Alert, 2024). Other influences on pastoralism are due to restrictions related to land-use changes, fragmentation of communal areas, political boundaries and ASAL developmental policies.

2.5 Gabbra Pastoralists in the Northern Rangelands of Kenya

The Gabbra are a Cushitic ethnic community and sub tribe of the larger Oromo people and who occupy the Central parts of Northern Kenya, in Marsabit, North Horr, Chalbi desert area, Moyale and Southern part of Ethiopia. The Gabbra community are perfect camel herders and they live around one of the driest areas of Kenya, the Chalbi desert, but also keep cattle, sheep and goats. The climatic and ecological characteristics on the northern rangeland of Kenya are hot, dry with vegetation being on a scale of arid to very arid with dry grasslands, bushlands, scrublands to desert type vegetation climaxed in Chalbi desert.

Despite the fact that their area of occupation is largely dry, foliage made up of grass, herbs and bush vegetation enables them to keep a mix of different livestock herds which include camels, cattle, sheep and goats as they feed at different ecological levels of preferred forage materials. Herd diversification and division of livestock to several small herd units is a strategy that protects against losses due to climate change (Latamo et al., 2022); perpetuated pasture losses, water scarcity, disease or livestock raids by other communities. The Gabbra, being nomadic, build simple traditional houses using materials obtained from the immediate environment, and which can easily be dismantled and carried along as part of their nomadism adaptation practices. The Gabbra's nomadic pastoralism lifestyle may appear simple but represents a very complex environment-social-cultural and economic system that exists in the midst of an ever-changing climate in the northern semi-arid and arid lands. The Gabbra community adaptations and resilience to climate change, ecological and social challenges are so outstanding and need to be studied and understood.

2.6 Pastoralism in the face of Climate Variables

Pastoral systems worldwide provide livelihoods for rural families in a wide diversity of social-ecological contexts, but particularly in the harsh environments of arid rangelands and high mountain pastures (Tittonell, 2021). Pastoralism serves not only as a food production system but also as a means of conserving rangeland biodiversity. These systems are highly dependent on the natural ecosystem and the functioning of pastoralist grazing systems can be a tool for the management of rangeland ecosystems, and especially those dominated by grass species through enriching low-quality soils and preventing bush encroachment through the combination of feeding habits of grazers and browsers (Nganga and Robinson, 2016).

Climate change, acting in combination with other human-related factors have in recent years been having devastating impacts in pastoralism. A study in Tana River found that threats to pastoralism included, climate change, over-exploitation of resources, uncontrolled human settlement patterns, farm encroachment, pollution, bush encroachment, inappropriate grazing patterns, flooding, land degradation, human–wildlife conflicts and non-native species invasion amongst others (Nganga and Robinson, 2016). Community adaptation to the negative impacts of climate change can benefit from an analysis of both the trends in climate variables and people's perception of climate change (Maingey, 2020). In most rural areas, local communities are able to observe changes in temperature and rainfall patterns and their perceptions can be positively correlated with meteorological records.

The Intergovernmental Panel on Climate Change (IPCC) predicts future higher temperature increases in most regions than the global mean temperature increase (Niang et al., 2014). This would mean an increase in hot nights, as well as longer and more frequent heat waves. For example, in Africa, the Western Sahel region in particular experiences the strongest drying, with a significant increase in the maximum length of dry spells (Niang, 2014). The impacts of climate change act to worsen existing vulnerabilities in Africa. This is particularly so as the region already endures high temperatures and low precipitation, frequent droughts, food insecurity and water scarcity (Kabubo-Mariara, 2008; Ozor et al, 2012). Examining the trends in rainfall and temperature over a period of at least thirty years is vital to assess climate-induced changes and suggest possible adaptation strategies. (Maingey 2020). A study in the southern Ethiopian rangelands on pastoralists' perception to climate change in the region was found to be very consistent with the actually recorded trends of increased temperature and the evident secular declines in precipitation and still, trends in the region's rainfall also appeared to have taken a direction of greater shifts towards unpredictability (Berhanu and Beyene, 2014). Analysis of climatic variables using appropriate tools to determine climate change (Nyakundi, 2022) and detection of changes in climate is an important prerequisite for a better understanding of the climate and developing adaptation and mitigation measures at a regional and local scale. (Gebrechorkos, 2019). These long-term seasonal trend analyses are supposed to show if temperatures and rainfall have been increasing or decreasing over time and if the observed trends are significant or not.

2.7 Climate Change and Pastoralism

Globally pastoralism is rapidly becoming threatened and strained by human population growth and the deterioration of rangeland resources (Tiwari et al., 2020; Belay and Siraj 2024), and also due to climate change that mostly result in water scarcity that depress ecological resources in pastures that offer nourishment to livestock as well as increased livestock disease incidences (Dong et al., 2016). In most areas of Africa where pastoralism is practiced water scarcity caused by climate changes is posing major challenges to traditional livestock production systems and more so since livelihoods of nomadic pastoralists almost wholly depend on rain fed livestock-based economy. Pastoralists in their livestock keeping regions are however, not unfamiliar with the management of climate variability and risks (Ericksen et al., 2013). For generations, several strategies which include herds manipulations, opportunistic grazing and mobility have been used in the fragile dryland ecosystems which experience a high range of temporal and spatial variations in both temperature and precipitation and which in turn determine availability or scarcity of fodder (Sandford & Scoones, 2006; Workneh et al, 2014).

Recent trends of rise in land-based investments in the Kenya have seen more and more investors targeting ASAL lands and especially group ranches, which are continuously being subdivided and put into varying uses, including sedentarization of livestock keeping or in extreme cases privatization and closing large tracts of lands to local pastoralists. Numerous scholars have shown that sedentarization of a previously mobile pastoral community increases the vulnerability of pastoralist groups (Western and Nightingale, 2004; Fan, et al 2015; Ripkey et al., 2021); since ASAL lands normally have low capacity to support crop farming or localized grazing due to aridity; in addition to the fact that most pastoralist communities are not familiar with sedentary livelihood practices. Sedentarization has been noted to be a constrained adaptation strategy at best because it increases the recursive use of rangeland and its fragmentation and forces livestock to move more intensively on a daily and seasonal basis. Wang, *et al* (2022

According to Ripkey *et al* 2021, pastoralists, are uniquely vulnerable to increased climate variability due to their dependence on weather conditions, which profile both the grazing land and water sources which provide the natural capital to sustain their livelihood. Sedentarization has however, in some instances been recognized as providing choices and incentives for local pastoralists to make changes to their daily life (Wang, et al 2015). In Kenya, land scarcity and population growth and climate change effects have resulted in increased sedentarization of pastoralists. Sedentary pastoralism entails converting nomadic pastoralists into herders who live in more or less permanent settlements. This may contribute to improving access to social services such as schools, health facilities, and water points (Sandford and Scoones, 2006), but may not be a solution to economic and cultural needs. Governments and non-governmental organizations still continue to promote sedentarization oblivious that nomadism is an adaptation that has evolved through generations driven largely by culture and abundance of community lands and the perception that it is limitless. There is also the belief among many donor agencies and government officials that support to the pastoral communities has been hampered their dispersed nature as they are mostly on the move. Livestock rearing, however, remains the main economic mainstay of most pastoralist communities and the primary source of milk, meat, income, and savings (Egeru *et al*., 2014). Despite increasing trends in sedentarization of pastoralists, a study among pastoralist groups of Northern Kenya (Nunow, 2024), has shown that mobility remains a vital adaptive mechanism for pastoralists, supporting both environmental sustainability and socio-economic resilience.

Some scholars argue that growing of food crops by ASAL communities only attracts the poorest pastoralists and who have been 'pushed' into economic livelihoods diversification by necessity rather than choice (Cuni-Sanchez *et al*., 2019), but this may not be the case as families with basic literacy levels tend to take to cultivation as additional occupation. However, while such under-takings have the potential to address food security and income demands, sedentarization has failed to achieve intended results. This is because in most instances it increases the recursive use of rangeland and its fragmentation and forces livestock to move more intensively on a daily and seasonal basis (Wang *et al*., 2022).

Pastoralists place multiple values on livestock. Aside from food (milk, meat, hides and blood), it provides transportation and draught power, a source of income to pay school fees or bride price, and an insurance value in times of adversity (Egeru, 2016). Furthermore, the cultural value of cattle breeding is extremely important because it impacts on cultural relationships and determines the valued aspects of honor, prestige and self-worth among pastoralist communities. The role of livestock is critical in establishing pastoralists' social status and prestige, as it is part of traditional rituals and related rites.).

Pastoralism is essential for the sustainable management and ecological health of dry lands, but also highly sensitive to increasing environmental degradation and global warming (Hartmann, 2010). Pastoralism is an occupation which appears to be fairly well adapted to the erratic climate and changing natural conditions of dry lands by providing and conserving ecosystems and their services in arid and semi-arid to arid areas. Due to climate change, agriculture including pastoralists' is undergoing great transformation that communities are not used to, the trend being towards higher vulnerability. Pastoral production systems depend on the availability of natural resources (mainly pastures and water) which are sensitive to climate change. In most arid and semi-arid areas most pastoralists are not able to pursue or diversify into other economic alternatives which makes them more vulnerable. The combined impact of land degradation and extreme weather conditions have been a major cause of pasture or fodder losses, and food insecurity in most arid and semi-arid areas. Livestock losses that follow are not only due pasture losses but also due livestock diseases due to low immune systems because of body emaciation (Gachene *et al*., 2024). In recent years there have been many consecutive droughts in Marsabit county which has affected livestock activities and consequently on Gabbra livelihoods.

2.8 Pastoralists Perceptions on Climate Change and its Stressors

There are many and overlapping factors that influence perceptions on climate change, and consequential adaptations. Herding experience, for example, is important because it is associated with experience and an attachment to a place or "home" and this eases in the identification and understanding of local environmental changes as they emerge. The older people tend to have a wealth of accumulated knowledge on the whole spectrum of livestock keeping value chain including localities key to them with regard to livestock economy (Akerlof *et al*., 2013). Such localities include areas with adequate security for the community and livestock, areas with new pastures, water sources and movement routes. Wealth status is seen as an enabler to accessing leadership status, honor, better extension services and this influences perceptions and consequently the ability to respond to changes that occur (Semenza et al., 2008). Indigenous knowledge on pastoralism livelihood systems, perceptions and response actions undertaken to overcome the impacts of climate change and variability is critical in guiding towards effective and locally acceptable adaptations.

Cuni-Sanchez *et al*. (2019) state that many pastoral groups apply local or indigenous knowledge to create more effective and regionally specific climate change adaptation strategies. While many communities have published a substantial amount of literature in the past ten years on their perceptions of climate variability and adaptation strategies, most of this literature has tended to focus on farming communities, particularly in rural agricultural landscapes where climatic conditions differ significantly from those in pastoral rangeland areas (Reyes-Garca et al, 2016). Pastoralist perspectives and adaptations have been the subject of numerous other research conducted throughout Africa (Filho et al., 2020), the majority of which have concentrated on the dry lowlands of East Africa.

In many regions, changing climates tend to produce great impacts on natural resources, changes in perceptions and consequently on human livelihoods. The practice of nomadic pastoralism is highly seasonal with areas and pattern of movements by a community or their segregated pastoral groups being around more or less regular known territorial circuits; with Pastoralists being in almost the same places or sites and in almost same times of the calendar; or cultural year. Perceptions are also highly conditioned around these patterns, and any slight deviation becomes a recipe for new perceptions. This is so with climate variations and change. Most pastoralism areas exhibit general geographical remoteness and extremes of climate variation especially in unpredictable diurnal temperatures and unpredictable rainfall patterns, which result in either intense droughts periods characterized by hunger, famine, human and livestock deaths related to humanitarian disasters. Conversely similar sufferings may result when flood disasters occur.

Water resources, in particular, rapidly change in dynamics due to climate variability and change (as a result of either increase or decrease in precipitation) with implications on natural water (in seasonal streams and rivers or in water pans or seasonal swamps or direct precipitation) dependent communities Gerten et al., 2004), and sectors and especially those involving rainfed crop farming and livestock keeping. A major constraint to securing water by communities is due to the fact that when there is too much rain water (floods), they do nothing to store this water for use when there is no rain. Rainfall and river flows are highly seasonal, so there is excess at some times and not enough at others. A community's perceptions on climate change and its effects or risks (Klein 2006); and its vulnerability status are key determinants of adaptation actions undertaken and consequential resilience.

2.9 Climate change Impacts, Adaptation and Resilience

In semi-arid areas climate change often leads to long periods of drought and occasional periods of very intense rains that result in flooding create the greatest impacts. They are often characterized by livestock losses and in extreme cases, humans. A study in Moyle District, Somali Regional State, Ethiopia reported that climate change resulted in periodic droughts, floods, elevated temperatures, and alterations in precipitation patterns (Salah 2024)0. These factors have an impact on the productivity of animals, the frequency of diseases, the patterns of breeding, the yields of crops, and collectively act to undermine socio-economic and cultural fabric of communities. As an example, climate-related risks lead to low milk yields by livestock and high livestock mortality, ultimately contributing to high poverty rates and destitution among pastoralists. (Berhanu and Beyene, 2014).

Climate change and its impacts on livelihoods is a key concern to many communities in developing countries. The wellbeing of marginalized communities is threatened by climate shocks such as droughts, heavy precipitation, floods and heat waves and tropical cyclones ((IPCC, 2021; Tofu, 2024). In arid and semi-arid areas (ASALs), severe drought causes significant disruption to natural ecosystems, biodiversity, water supply and agricultural production. Many communities in sub-Saharan Africa commonly practice pastoral systems, which combine cultivation of crop and rearing of livestock (FAO, 2021). The communities that practice pastoral systems derive economic benefits (e.g., primary source of income, food security, asset and wealth storage and employment); socio-cultural (e.g., cultural identity, social status and prestige and social capital) and environmental benefits (e.g., sustainable land use and biodiversity preservation).

The attainment of Sustainable Development Goal (SDG) on eradicating poverty (SDG1) and on food security (SDG2) has been a big challenge in many developing countries in sub-Saharan Africa (Biswas *et al*., 2021). The situation in most ASALs has been exacerbated by climate variability and change. Ecosystem degradation, alteration of hydrological cycle, poor agricultural yields and reduced food supply have forced communities to adopt maladaptation practices, such as overstocking and charcoal burning, thus worsening the situation (Mahmood *et al*., 2021). Therefore, climate variability and change pose uneven and severe threats to many communities in ASALs of sub-Saharan Africa.

Climate information is one of the essential factors for effective adaptation to climate variability in pastoralism (Kedir and Tekalign, 2016). Early warning systems, collection of reliable climate data, disaster risk reduction and risk sharing are important elements for enhancing adaptations. Such information among pastoralist communities become much more useful when supplemented by their indigenous knowledge, Pastoralist adaptation response strategies broadly involve adjustments in pastoral practices and shifts to non-pastoral livelihoods (Berhanu and Beyene, 2014). Among pastoralist communities many other factors such as those related to gender, land (Nkuba *et al*., 2019) among others factors are important in adaptations undertaken and need to be understood. In semi-arid areas, which are central to the pastoral economy, Local institutions have also been noted to play a key role in facilitating adaptation (Yomo, 2024). Public policy focusing on information accessibility, encouraging environmental awareness and conservation and promoting social inclusion through informality acts to strengthen the resilience of communities to climate change (Kapruwan ., 2024).

2.10 Vulnerability of Communities to Climate Change

According to the Intergovernmental Panel on Climate Change (IPCC) Africa is one of the most vulnerable continents to climate change and climate vulnerability (IPCC 2007a) and that by the 2050s, 350–600 million Africans will be at risk for increased water stress, predominantly in the northern and southern parts of the continent (IPCC, 2007a). Climate vulnerability describes the degree to which natural, built, and human systems are at risk of exposure to climate change impacts. Changing climate places direct and indirect impacts on human activities and is mainly triggered by non-climatic stressors, which are diverse and inherent in many communities (Mabhuye, 2024). Four types of vulnerability are Human-social, Physical, Economic and Environmental and their associated direct and indirect losses. Vulnerability in a community may be due to factors such as poverty, race, gender, and special needs populations. A study carried out in North-Western Highlands of Tanzania identified major climate stress factors for communities' to include seasonal variability of rainfall and temperature increase, which influenced the increase of pests and diseases and other unfavorable climatic conditions that affect crop production and livestock keeping (Mabhuye, 2024). Such factors act to undermine crops and livestock productivity consequently leading to food insecurity and reduced incomes, and increased poverty which further exposes communities to further climate change vulnerabilities; and which may be magnified by non-climate stress factors.

Climate change impacts tend to severely destroy livelihoods of vulnerable populations and are exacerbated by socio-economic and political inequalities, while in many instances, adaptation and mitigation actions remain inadequate or ineffective. In pastoralist societies, different groups are impacted differently by climate change based on factors such as age, sex, wealth, economic status and rank in the society, ownership of different livestock species, economic engagement, as well as geographical location (Mushi, 2013). A study in the horn of Africa (Musau, 2021) noted a close nexus between women's vulnerability and climate change. In particular, climate change in the horn of Africa is exacerbated by factors such as gender roles among pastoralist communities; access to and control of vital resources such as water, livestock products and fuelwood, status of pastoralist women regarding decision making; other factors among others. Among nomadic communities in Northern Kenya, climate-induced migration of men with their livestock to places with better pastures and water increase the household workload of women, while at the same time denying them incomes from sales of milk from livestock which they migrate with. In addition to women, others vulnerable include the aged, children and people living with disabilities and indigenous people who are also very vulnerable to climate change impacts (Kosanic 2022).

2.11 Vulnerability of households to climate change

Studies assessing vulnerabilities on households, communities or societies to climate change and how they adapt to changing environmental conditions tend to increasingly use analytical approaches (Füssel and Klein, 2006). The overarching goal of these analytical approaches is to identify both the impediments or obstacles as the needs and practical opportunities for future adaptations and documenting sensitivity of communities to changing conditions; including their intrinsic coping mechanisms. Understanding current sensitivities and adaptation initiatives and processes is seen as a good starting point when considering future exposures and adaptations.

Many studies on the effects of climate change have defined vulnerability in terms of physical stimuli and their consequences or residual effects. The vulnerability viewpoint is concerned with the nature, distribution and thresholds of hazardous or stressing conditions as they affect human occupancy, as well as the extent of loss or suffering associated with occurrence of specific events. Another perspective on vulnerability focuses on a social system or community's pre-existing conditions that makes it vulnerable to harm. This interpretation focuses on the factors and processes that influence a community or a society's susceptibility to stimuli and ability to deal with hazards (Downing, 2003). Social system characteristics such as marginality, inequity, exclusion, the presence and strength of institutions, food and resource rights or entitlements, literacy, economics, and politics can all increase (or decrease) vulnerability (Smit and Pilifosova, 2003). Equally governance structures used in managing communal ecosystems and resources can determine the extent and direction of vulnerabilities associated with climate change.

2.12 Livelihood Vulnerability Index

The need to understand the impacts of climate change impacts on poor and vulnerable communities cannot be underrated. Vulnerability Index (LVI) is used to assess the vulnerability of farmers to climate change impacts based on factors such as socio-demographic characteristics and adaptive capacity. The LVI combines various indicators related to these dimensions, such as socio-demographic profile, livelihood strategies, health, and social networks, to provide a comprehensive assessment of vulnerability (IPCC, 2007a; IPCC, 2007b).

Climate vulnerability assessments are important in quantifying how communities adapt to changing environmental conditions. According to IPCC 2021, vulnerability can be viewed as a function of exposure, sensitivity, and adaptive capacity. Exposure in this case is the magnitude and duration of the climate-related exposure such as a drought or change in precipitation, sensitivity is the degree to which the system is affected by the exposure, and adaptive capacity is the system's ability to withstand or recover from the exposure (Ebi ., 2006).

The LVI uses multiple indicators to assess exposure to natural disasters and climate variability, social and economic characteristics of households that affect their adaptive capacity, and current health, food, and water resource characteristics that determine their sensitivity to climate change impacts ((IDA, IPWDGN and EIWEN, 2023)

2.13 Vulnerability to climate change and adaptation strategies among the Gabbra

Pastoralists living in Kenya's northern rangelands' or ASAL environments have in recent decades been vulnerable to the effects of climate change and variability, particularly due to the recurring nature of prolonged droughts, floods, and conflicts. What is most striking is the fact that vulnerability among the Gabbra pastoralists has continuously been on the rise. Most of the areas occupied by the Gabbra pastoralists also face limitations of being physically and socially isolated, and have limited government services available. As such, the majority of the Gabbra pastoralists remain isolated because of low levels of participation in national economies. As a result, most of the Gabbra pastoralists especially in areas with no road infrastructure or schools rank high in terms of poverty levels and social welfare. Important quality of life indicators (e.g. education levels, maternal health, nutritional status especially among women and children is usually very low. Just as in most other pastoral areas, rains bring relief to the Gabbra communities as water and pastures become available, but which only lasts for only one season, sometimes a short season as the northern rangelands are characterized by high levels of aridity.

During rains pastures are plentiful in the landscape including open fields where grass and herbs sprout with water occurring in natural catchments and along seasonal rivers which rapidly shrink as dry season commences. As dryness advances, water becomes available only in a few natural springs, wells, water pans and boreholes, some which gradually dry up leading to a situation where both pasture and water become extremely scarce. For many years the Gabbra pastoralists have had their own coping mechanisms and/or adaptation strategies to mitigate the effects of localized climate-related hazards. As such they undertake various forms of adaptations as well as coping strategies to the impacts of climate variability and change.

The many years of rich experiences in nomadism practices contributes much to the Gabbra people on how to survive under extreme environmental change. Their adaptation and coping strategies are closely guided age-old traditions or cultural structures and values which supervise socioeconomic/cultural, political, and environmental/ecological issues. Among the adaptation mechanisms are pastoral mobility, reliance on traditional indicators of change or early warning signs, area enclosures and hay/forage preparation, livestock diversification and species selection, and the transition from pure pastoral to -pastoral production systems. Selling small stock (sheep and goats), sharing resources with relatives/ clan members, herd splitting, mobility, engaging in labour work in nearby towns/urban centers, and changing food intake are among the most common strategies used by pastoralists (quantity and timing). The pastoralists' coping strategies include charcoal and honey production, firewood collection, as well as the sale of their livestock, hides and skins. However, the capacity of these traditional coping and adaptation strategies are limited due to continuously increasing intensity and severity of the climate change-induced hazards and occasional conflicts experienced in these regions. The Pastoralists communities at times receive food aid from both government and non-governmental organizations.

2.14 Literature gaps

Many efforts have been made to comprehend how communities in Kenya's rangelands perceive, react and adapt their livelihood strategies in response to increasing climate variability and change. Impact models on climatic variability and change including adaptation studies on specific sectors such as water resources, agriculture, health, and related vulnerabilities have been conducted severally using and, to a lesser extent, socio-economic analyses (Nassef *et al*., 2009). Concerning the situation in Marsabit County's Gabbra areas, an important gap exists in terms of the nature of climate change impacts; parameters and groups affected and extents in relation to current vulnerabilities at the local level; and in particular among the Gabbra people. Literature detailing ongoing adaptation strategies and indigenous adaptive responses, including at the community level, is also lacking; information on how communities perceive and adapt to climate variability and change is also needed to guide future adaptation strategies and policies, and these gaps need to be filled. Other gaps identified include historical and current climatic models in Kenya's northern rangelands, the effects of overlap of climatic generated challenges as well as Indigenous knowledge and climate change among Gabbra communities.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 The Study Area

The study area covers all the Marsabit Sub-counties where the Gabbra community is found within the expansive Marsabit County. Covering an area of more than 70,961.2 square kilometers, Marsabit County is an arid and semi-arid region (ASAL) in the heart of northern Kenya and is defined by Latitude $02^{0}45'N$ and $04^{0}27'N$ and longitude $37^{0}57'E$ and $39^{0}21'E$. Ethiopia lies to the north of Marsabit County; Lake Turkana lies to the west; Samburu County lies to the south; and Wajir and Isiolo counties lie to the east.

The area has characteristic broad plains that rise to a height of 300 to 900 meters above sea level and gently sloping to the South-west making up the largest portion of Marsabit County. The plains are encircled by hills and mountain ranges to the West and North, several of which have calderas and volcanic cones. Mt. Kulal in the Northwest, which stands up at 2,235 meters, is the highest peak. Marsabit County receives an average annual precipitation of 254mm ranging between 200 and 1000mm, which make Marsabit to be one of most dry counties in Kenya (Kirui *et al.,* 2022). Chalbi Desert is in this county.

3.1.1 Climate of Marsabit County

Daytime temperatures are generally high, often ranging between 25°C to 35°C. Nighttime temperatures can drop significantly, especially in higher-altitude areas like Marsabit town, where it can get quite cold. The county receives low and erratic rainfall, typically between 200mm to 500mm annually. Rainfall patterns are bimodal, with two rainy seasons: the long rains from March to May and the short rains from October to December. Droughts are common and can last for extended periods.

Humidity levels are generally low due to the arid conditions, contributing to the dry environment. The region can experience strong winds, especially during the dry seasons, which can lead to dust storms. The arid climate supports sparse vegetation, primarily consisting of shrubs, grasses, and acacia trees. The landscape is dominated by semi-desert and savannah ecosystems. The dry season is typically hot and dusty, while the rainy season brings some relief with cooler temperatures and greener landscapes, though the rains can be unpredictable.

3.1.2 Physical and Topographic Features

The County falls within an arid and semi-arid area which constitutes an extensive plain lying between 300 and 900 m above sea level, sloping gently towards the southeast. The plain is bordered to the west and north by hills and mountain ranges and is broken by volcanic cones and calderas. The most notable topographical features of the county are Ol Donyo Ranges (2,066m asl) in the south west, Mt. Marsabit (1,865m asl) in the central part of the county, Hurri Hills (1,685m asl) in the north eastern part of the county, Mt. Kulal (2,235m asl) in the north west and the mountains around Sololo-Moyale escarpment (up to 1,400m asl) in the north east. There are no permanent rivers in the county, but four drainage systems exist, covering an area of 948 sq km.

Chalbi Desert is the largest of these systems. The extensive Chalbi Desert which forms a large depression covering an area of 948 sq km, lying between 435 and 500m elevation. The depression is within the Great Rift Valley and is separated from Lake Turkana, which is 65 -100m lower in elevation, by a ridge that rises to 700m. There are no permanent rivers in the county, but four drainage systems exist, covering an area of 948 sq km. Chalbi Desert is the largest of these systems. The seasonal rivers of Milgis and Merille to the extreme south flow eastward and drain into the Sori Adio Swamp. Other drainage systems include the Dida Galgallu plains which receive run-off from the eastern slopes of Hurri Hills, and Lake Turkana into which seasonal rivers drain from Kulal and Nyiru mountains.

3.1.3 Vegetation of Marsabit County

The typical vegetation is dwarf-shrub grassland or a very dry form of bushed grassland. The extremely dry areas may be properly termed “bushed stoneland”. The zone includes all the hills and plains below 700m. These grassland areas are interspersed with short bushes and trees which give way to dwarf Scrubland as aridity increases.

The county has one indigenous forest known as Mt. Marsabit, with a size of 152.8 km2 and is home to Marsabit Game Reserve and Sibiloi National Park. Marsabit forest, with its endemic flora and fauna, is the only gazetted forest in the county. There are two forests, Mt. Kulal and Hurri hills which are non gazetted forests, and have a total area of 750 km^2.

3.1.4 Population of Marsabit County

Over the years, Marsabit county has experienced rapid population growth. In 2009, the total population of Marsabit county was 291,069 persons that is 151,061 males and 140,011 females, while in the last census of 2019 the total population was 459,785 persons, comprising 243,548 males and 216,219 females. Over a period of 10 years, the total population grew by 168,716 constituting a growth rate of almost 58%. From the demographic summary of the population, the proportion of male to females is still high across most of the cohorts. The youthful population of the county below the age of 19 is more than half the total proportion of the population accounting to 58% of the total population. This shows that the county requires urgent investment in education, health, nutrition and water to avoid instances of strain on the existing investments. Population growth should also be managed to allow for a sustainable growth pattern.

3.1.5 Economic Activities in Marsabit County

Although agricultural production in the county includes diverse activities - livestock keeping, crop production, bee keeping, fishing and agroforestry is the main economic activity in the County, the livestock keeping predominates. Approximately 81%, 16%, and 3% of the population is engaged in pastoralism, agro-pastoralism, and other livelihoods respectively. The livestock types reared in the county include cattle, goats, sheep, camels, donkeys, and poultry. Bee keeping is also practiced, and fishing is mainly done in the Lake Turkana area. The crops grown are maize, green gram, wheat, teff, beans, millet, vegetables (kales) and fruits (mangoes, oranges and avocados). Fruit trees are considered as part of agroforestry, a practice limited to areas around Mt. Marsabit and Sessi in Moyale. However, the low and erratic rainfall in most parts of the county restricts crop production to few areas.

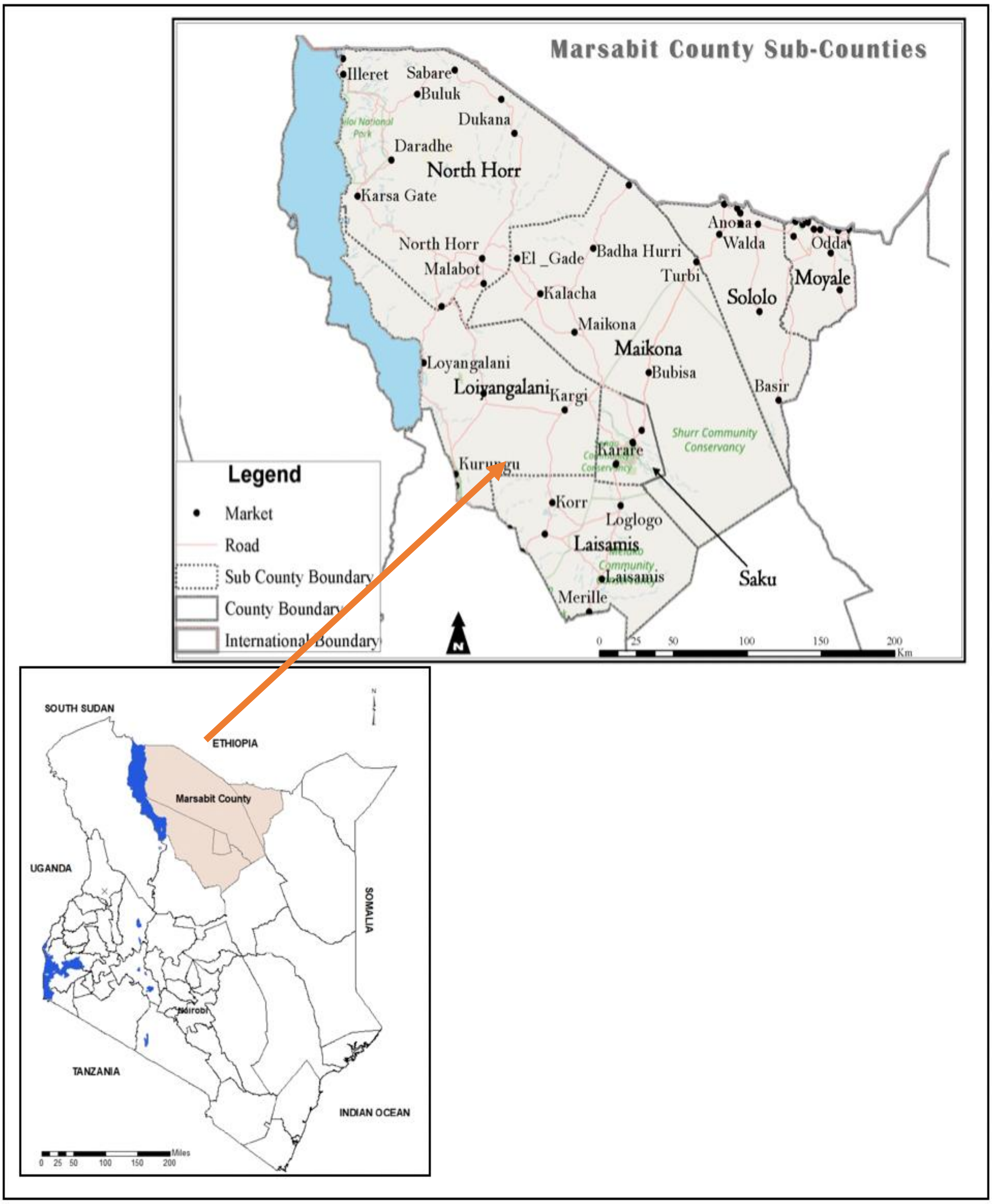

Figure 3.1 The study area of Gabbra area in Marsabit County, Kenya

Source: Author, 2022

Much of Marsabit county has an arid climate, with the exception of a few isolated areas around Mt. Marsabit, Mt. Kulal, Hurri Hills, and the Moyale-Sololo escarpment, which are typical semi-arid; and whose surroundings are important livestock grazing grounds. The temperature ranges from 15^0 to 26^0 degrees Celsius, an average of 20.5^0 degrees Celsius annually (World Weather and Climate Information, 2015). The precipitation pattern is bimodal with the peak being experienced between April to May. Rainfall ranges from 200mm to 1,000mm per year and is affected by altitude and slope direction both which to an extent determine rainfall duration, amount, and reliability. Mt. Marsabit and Mt. Kulal receives 800mm of rain per year, while lying North Horr (altitude 550m) receives about 150mm.

The Gabbra ethnic group which mostly practices nomadic pastoralism primarily inhabits Hurri Hills. There are an estimated 100,000 of them (Kenya National Bureau of Statistics, 2019). Gabbra have employed a livestock management system in which families rely primarily on milk more than meat for daily nutritional requirements. Mature animals are regularly sold to obtain cash for various economic needs while others are retained to increase livestock numbers or herd sizes, and for prestige, wealth and social status purposes, and also to act as a buffer against death risks that may be occasioned by disease pandemic or severe droughts.

3.2 Research Design

Mixed (quantitative and qualitative) research design was used in this study (Lund, 2012). This included: a descriptive study with (both quantitative and qualitative aspects; and a time series study for temperature and precipitation trend analysis, determinants of climate change adaptation choices and vulnerability analysis. Also covered in the study was a cross-sectional analysis of perceptions about climate change, and adaptation to climate change among the Gabbra pastoralists.

3.3 Sampling Procedure and Sample Size

The seven Sub-counties in Marsabit are Loiyangalani, Marsabit South, Marsabit Central, Marsabit North, North Horr, Moyale, and Sololo. The Gabbra Community is predominantly found in North Horr and Marsabit North. All Gabbra households that practice pastoralism were included in the sampling frame (Table 3.1). In accordance with the calculated sample size, systematic random sampling (Kothari, 2019) was used to select households from all sub-counties. In order to ensure the randomness of the starting point., a random number generator was used in the study.

3.4 Sample Size

The sample of households was determined using Yamane Formula (Yamane, 1973)

$$n = \frac{N}{1 + Ne^2} \quad (3.1)$$

Where n = sample size; N = Households; e = error (0.05) reliability level 95%; or; e = level of precision always set the value of 0.05.

$$n = \frac{77495}{1 + 77495 * 0.05^2} = \frac{77495}{194.74} = 397.9 \approx 398$$

Table 3.1 Sampling procedure

Sub-County	Pastoralist Households	Sample Size	Percentage (%)
1. Loiyangalani	7,774	40	10.05
2. Marsabit South	11,615	60	15.08
3. Marsabit Central	15,849	81	20.35
4. Marsabit North	7,521	39	9.80
5. North Horr	9,789	50	12.56
6. Moyale	17,709	91	22.86
7. Sololo	7,238	37	9.30
Total	**77,495**	**398**	**100.00**

3.5 Research Instruments

The secondary (i.e., time series) data on temperature and precipitation for Marsabit County was obtained from Kenya Meteorological Department in Marsabit County. This was to enable analysis of temperature and precipitation trends and patterns from 1990 to 2022. Questionnaires, key informant interviews, focus group discussions, and observation schedules were the key research instruments used in the study, an observation schedule was used in the cross-sectional survey in Marsabit County. In order to collect quantifiable data from a large number of participants, the researcher used a semi-structured questionnaire. This was aimed at collecting quantitative and qualitative data to evaluate the perceptions about the impacts of climate change as well as adaptation strategies from respondents.

3.6 Data Collection

The analysis of trends demands lengthy time-series data in order to reliably detect trends in rainfall and temperature. In this study, secondary data for rainfall and temperature was obtained from the Kenya Meteorological Department for the period from 1990 to 2022. Using KoBo-Collect survey tool, which is an open-source Android app for collecting data in offline situations, a semi-structured questionnaire was administered among the Gabbra Pastoralists in Marsabit County. A sample of 398 households was selected for data collection after piloting the instruments. The sample was selected from seven sub-counties where Gabbra communities are resident (Table 1). The collected primary data was on climate change perceptions, impacts, adaptations and additionally on household vulnerability to climate change while secondary data, which was obtained from the Kenya Meteorological Department, was on rainfall and temperature. One focus group discussion was conducted for each sub-county in Marsabit County. This included the knowledgeable pastoralists and community leaders in the study area. The key informants for this study included officials from: Pastoralist People's Initiative (PPI), Pastoralist Concern (PC), Pastoralist Integrated Support Programme (PISP), Pastoralist Community Initiative and Development Assistance (PACIDA), Kenya Agricultural and Livestock Research Organization (KALRO), County Government and local administrators.

3.7 Piloting of the Instruments

Piloting of the research instruments was carried out in two sub-counties of Marsabit namely: Marsabit Central and Loiyangalani. Households for the pilot study were randomly sampled Small samples of twenty (10) households in each of the two areas were sampled with the aim of testing the efficacy of the instrument. The results of the pilot study were used to revise the data collection instruments, taking into consideration respondents' views before the full survey was undertaken.

3.8 Validity and Reliability Tests

Validity and reliability are two types of criteria that contribute to the quality of the questionnaire. Carmines and Zeller (1979) define reliability as the consistency and stability of measuring results for a phenomenon. Reliability is also concerned with repetition. A scale or test is considered dependable if it produces consistent results when repeated under constant conditions (Taherdoost, 2016). Reliability testing ensures uniformity across a measuring instrument's components. The Cronbach Alpha coefficient is the most widely utilized internal consistency measure. This is considered the most reliable measure.

3.9 Quantitative Data Analysis

The Mann-Kendall and Sen's slope models was used to examine temperature and precipitation trends in Marsabit County between 1990 and 2021. The Mann-Kendall (MK) non-parametric trend test (Mann, 1945, Kendall, 1975) was used to detect monotonic trends in temperature and rainfall (identify the presence of a trend), and Sen's estimate (Sen, 1968) was used to assess the magnitude of the trend. The 95% confidence level was used to determine the significant trends for temperature and rainfall data.

3.9.1 Mann-Kendall Test (MK_1)

Mann-Kendall (MK) test is used to determine monotonic upward or downward trend in a time series data. This test does not require the assumption of data normality because it is non-parametric. MK is also less sensitive to sudden breaks, which are instigated by non-homogenous time series. It is based on two hypotheses: the null hypothesis (H_0) which indicates no trend (no change in the series mean) and the alternative hypothesis (H_1) which indicates the presence of a monotonic trend (a rise or decrease in the mean over time).

The MK test uses the time series of k data points and considers x_i and x_j as two data subsets where i = 1,2, 3, ..., k-1 and j = i + 1, i + 2, i + 3, ..., k. The data values are assessed as an ordered time series and every data value is compared to the subsequent data values. When the data value of a subsequent period of time is less than a previously sampled data value, the S statistic is reduced by one. However, if the data value of a subsequent period exceeds that of the previous period, the S statistic is increased by one. The total of all these decrements and increments results in the final value of S (Drapela and Drapelova, 2011). The Mann-Kendall test statistic (S) is thus, calculated as follows:

$$S = \sum_{i=1}^{k} \sum_{j=i+1}^{k} sign(x_j - x_i)$$

(3.2)

Where, k is the total number of data points, x_i and x_j are the data values in time series i and j (j>i), and sign(x_j - x_i) is the sign function. The sign function is calculated as shown below:

$$sign(x_j - x_i = \{1, if\ x_j - x_i > 0\ \ 0, if\ x_j - x_i = 0\ -1, if\ x_j - x_i < 0\ \}$$

(3.3)

The positive and negative values of S imply upward and downward trends respectively (Silva, *et al.*, 2015). If the time series is sufficiently long (number of data values, k≥10), the S statistics behave essentially normally, and the test is done using a normal distribution with the mean E(S) and variance V(S) as indicated in equations 3.4 and 3.5.

$$E(S) = 0$$

(3.4)

$$V(S) = \frac{k(k-1)(2k+5) - \sum_{i=1}^{y} z_i\,(i)(i-1)(2i+5)}{18}$$
(3.5)

Where k is the number of data points, y is the number of tied groups and z_i is the number of ties to the extent of i. The standard normal test statistic Z_S is computed as:

$$Z_s = \left\{ \frac{S-1}{\sqrt{V(S)}}, if\ S > 0\ 0, if\ S = 0\ \frac{S+1}{\sqrt{V(S)}}, if\ S < 0 \right\}$$
(3.6)

The negative Z_S values indicate decreasing trends whereas positive Z_S values infer increasing trends. A Z-test statistic offers significance levels (SL) for rejecting the null hypothesis. The confidence level (CL) for rejecting the null hypothesis is specified as:

$$CL = 1 - SL$$
(3.7)

The null hypothesis was rejected when $|Z_s| > 1.96$ by adopting a 5% significance level in this study.

3.9.2 Serial Correlation Effect

Serially independent data is required for Mann-Kendall test. Since time series data is frequently autocorrelated, the trend detection is usually affected by the presence of serial correlation. The presence of positive autocorrelation may lead to the rejection of a null hypothesis thus leading to type 1 error. On the other hand, Type 2 error might occur when the null hypothesis is not rejected in the presence of a negative autocorrelation (Kumar *et al.*, 2009). When serial correlation is detected in a time series, it should be removed in order to appropriately assess the significance of trends. There are several methods that have been proposed to account for the effect of auto-correlation in natural time series data. In this study, This study's pre-whitening technique was used to reduce the impact of serial correlation on the MK test.

3.9.3 Mann-Kendall trend test with trend-free pre-whitening (MK_2)

Pre-whitening is a technique that is employed on autocorrelated series to convert it into an uncorrelated one ("white noise" hence the term whitening) before applying a trend test (Yue *et al*., 2002, Hamed, 2009). This study used the Trend-Free Pre-whitening procedure whereby lag-1 serial correlation components were eliminated from the series before the MK test. The lag-one autocorrelation coefficient (r_1) was computed using the following equation:

$$r_1 = \frac{\frac{1}{k-1}\sum_{i=1}^{k-1}(x_i - \underline{x})(x_{i+1} - \underline{x})}{\frac{1}{k}\sum_{i=1}^{k}(x_i - \underline{x})^2} \quad (3.8)$$

Where x_i represents a value of an observation in a time series, $\bar{x}$ denotes the mean of the time series data sample, and k symbolizes the sample size. The autocorrelation coefficient values were tested using the following equation:

$$r_1 = \frac{-1 \pm 1.96\sqrt{(k-2)}}{k-1} \quad (3.9)$$

When r_1 was between the upper and lower boundaries of the confidence interval, the time series data were deemed to be serially correlated. As a result, the trend-free pre-whitening technique, which is a modified MK test, was applied. The equation 9 was used to eliminate the trend and obtain a detrended time series data:

$$x'_i = x_i - (\beta * i)$$
(3.10)

Where:

$$\beta = median\left|\frac{x_j - x_i}{j-i}\right| \; for\; all\; i > j$$
(3.11)

The lag-1 autocorrelations for detrended time series, which are given by $x'i$, were calculated using equation 7. In order to find a residual series, equation 11 was used to eliminate the lag-1 autoregressive component (AR(1)) from the detrended series.

$$y'_i = x'_i - r_1 * x'_{i-1}$$
(3.12)

$$y_i = y'_i + (\beta * i)$$
(3.13)

3.9.4 Sen's Slope Estimator

Mann-Kendall test is used to detect the presence of a trend while Sen's slope estimator is employed to evaluate its magnitude. Sen's slope test assumes a linear trend and characterizes the quantification of temporal change. This test is preferred over linear regression in hydro-meteorological investigations since its robustness against the effect of outliers (Zhang *et al*., 2005). Sen's slope equation for trend slope estimate (Q) in a sample of M pairs of data is as follows:

$$Q_i = \frac{x_m - x_n}{m - n} \; for \; i = 1,2,3 \ldots Z$$
(3.14)

Where x_m and x_n represent data values at times m and n (m>n) respectively, and Z denotes the total number of slope observations. Sen's estimated slope is the median of the Z values associated with Qi. Based on the slopes value of Z, the median of all slopes is ranked from lowest to the highest Qi as follows:

$$Q = \left[Q\frac{Z+1}{2} \; if \; Z \; is \; odd \; \frac{1}{2}\left(Q\frac{Z}{2} + Q\frac{Z+1}{2} \right) \; if \; Z \; is \; even \right]$$
(3.15)

Where:

$$Z = \frac{k(k-1)}{2}$$

(3.16)

3.10 Perceptions, Impacts and Adaptation to Climate Changes

The study used descriptive statistics to describe the perceptions, impacts and adaptation strategies adopted. Since the survey data obtained for the objective was categorical, proportions were employed in analysis. The adaptation to climate change by the Gabbra pastoralists included strategies targeting soils, crops and livestock. The obtained results were then presented using tables, doughnut charts and bar graphs.

The study tested a null hypothesis that socioeconomic, institutional and ecological factors variables have no impact on the choice of dependent variables (cultivating early maturing cultivars as a mitigation strategy; destocking as a climate mitigation strategy; and use manure for soil amendment as a mitigation strategy) pastoralists chose an adaptation strategy if the expected utility from it exceeded that of other adaptation strategies such that:

$$Y^* = Y_i \; If \; U_i > U_j$$
$$= Y_j \; If \; U_i \leq U_j$$

(3. 17)

Where, Y_i represents the strategy type i, Y_j an alternative strategy type j, U_i and U_j the related expected indirect utility values of strategy type i and its alternate j, while Y^* represents the strategy type chosen. As a result, a random utility discrete choice model may be used to analyse pastoralists' options regarding adaptation strategies. Because it is an indirect utility function—that is, it associates an average utility level with each possible adaptation method in a choice set—this is especially suitable for modelling discrete choice options, such as those between adaptation techniques. Within this framework, it is assumed that every farmer is aware of the utility function; however, the researcher is not aware of all of its components. We treat this portion of the utility that is not observed as a random variable. Next, the expected indirect utility for the i strategy selection was modelled as the total of the observable variables plus the non-observed random component:

$U_i = \beta'_i X_i + \varepsilon_i$

(3. 18)

The choice utility of implementing any alternatives can be expressed as follows, much like in Equation (3.17):

$U_j = \beta'_j X_j + \varepsilon_j$

(3. 19)

where the parameter vectors are β'_i and β'_j. Farmers can therefore concurrently determine, based on the vectors of the explanatory variables X_i and X_j, whether to select one or more adaptation techniques. With this method, we may examine the farmers' collective decisions on adaptation strategy by using a multivariate Probit model. Equations (2) and (3) are followed by empirical model specification, which is as follows:

$Y^*_{ij} = U_i = \beta'_i X_i + \varepsilon_i$

(3.20)

With i = 1, 2, 3

$Y_i = 1 \; if \; Y^*_i > 0 \; and \; 0 \; otherwise$

Where, for i = 1 (cultivating early maturing cultivars as a mitigation strategy), i = 2 (destocking as a climate mitigation strategy), and i = 3 (use manure for soil amendment as a mitigation strategy), Y^*_j is an unobservable latent variable representing the likelihood of selecting j kind of adaptation strategy. Consequently, the model can be stated empirically as:

$Y_i = \beta_i X_i + \varepsilon_i$

(3. 21)

Whereas the following values correspond to different scenarios: $Y_i = 1$ for cultivating early maturing cultivars as a mitigation strategy (0 otherwise), $Y_i = 2$ for destocking as a climate mitigation strategy (0 otherwise), and $Y_i = 3$ for use manure for soil amendment as a mitigation strategy (0 otherwise). X_i = vector of parameters (gender of household head, age of household head, education of household head, monthly income, household size, membership to social group, increasing temperature, unpredictable rainfall patterns, increased drought frequency , assistance from government, assistance from relatives, access to extension services, access to credit services, water availability, pasture availability, and own large herd of livestock) impacting the choice of strategy to mitigate climate change, and ε = is the error term.

Since multivariate Probit analysis performs better than other competing methods in terms of efficiency and effectiveness in minimizing heteroscedasticity and the error term has a conventional normal distribution, it is the ideal model to prevent heteroscedasticity (Gudere *et al*., 2023). The variance inflation factor was used to determine whether there was multicollinearity among the explanatory variables (Dougherty, 2021).

3.11 Livelihood Vulnerability Index

This study employed two methods to analyze the livelihood vulnerability of the Gabbra Community in Marsabit County: the composite Livelihood Vulnerability Index (LVI) and the Intergovernmental Panel for Climate Change (LVI-IPCC) vulnerability index.

3.11.1 Livelihood Vulnerability Index: Composite Index Method

Livelihood vulnerability index (LVI) has seven chief components: socio-demographic, livelihood strategies profile, health, food, water, climate variability and natural disasters, and social networks (Figure 3.2). In Marsabit County, the analysis of composite LVI for each major component was based on specific and related subcomponents (Hahn *et al*., 2009). This approach was employed in each sub-county. In order to ensure that each sub-component contributes equally to the overall index, a balanced weighted average approach is utilized. Since each sub component is assessed on a distinct scale, standardization is performed in order to generate an index for each of them. The equation used for standardization is:

$$index_{s_c} = \frac{S_c - S_{min}}{S_{max} - S_{min}}$$

(3.22)

Where s_c is the sub-component for sub-county c, and s_{min} and s_{max} are the minimum and maximum values derived using data from sub-counties. The minimum and maximum values for variables that measure frequencies, such as percentage, were set to 0 and 100, respectively. To get the value of each major component, the sub-components are averaged and then standardized using equation (3.23) (Hahn *et al.*, 2009).

$$M_c = \frac{\sum_{i=1}^{n} index_{s_{ci}}}{\sum_{i=1}^{7} W_{M_i}}$$

(3.23)

Where n is the number of sub-components in each main component, $index_{sc}$ is the sub components that make up each main component indexed by i, and Mc is one of the seven major components for sub county (c) (Basiru *et al.*, 2022). After determining the values for each of the seven main components for each sub-county, they were averaged using equation (3.25) to generate the overall LVI score for gender.

$$LVI_c = \frac{\sum_{i=1}^{7} W_{M_i} M_{c_i}}{\sum_{i=1}^{7} W_{M_i}}$$

(3.24)

LVIc represents the weighted average of the seven primary components, which is called the Livelihood Vulnerability Index for the sub-county. The number of sub-components that make up each main component determines the weights of each major component. In this study, the scale which ranges from 0 (least vulnerable) to 0.5 (most vulnerable) was adopted as developed by Hahn *et al.*, (2009). The major components and their respective subcomponents are provided in Table 2.

3.11.2 Framework Method for LVI-IPCC

The LVI-IPCC method was also used to determine livelihood vulnerability to climate change in Marsabit County. This approach groups the seven primary components of LVI into three vulnerability contributory factors: exposure, sensitivity and adaptive capacity (Table 3.3). Equations (3.22), (3.24), and (3.25) are used in computing the LVI. However, in the LVI-IPCC technique the primary components of the LVI are not combined into the LVI in one step as they are in the composite LVI method. In this case, they are first combined into LVI using the following equation:

$$CF_c = \frac{\sum_{i=1}^{n} W_{M_i} M_{c_i}}{\sum_{i=1}^{n} W_{M_i}}$$

(3.25)

Where CF_c is an IPCC definite vulnerability contributing factor for sub-county c, M_{ci} is the main component for subcounty c indexed by i, W_{Mi} is the weight of each major component and, n is the total number of major components in each IPCC contributory factor. After determining exposure, sensitivity and adaptive capacity, the LVI-IPCC is calculated by integrating the three vulnerability contributory factors using the following equation:

$$LVI - IPCC_c = (e_c - a_c) * s_c$$

(3.26)

Where $LVI\text{-}IPCC_c$ denotes the Livelihood Vulnerability Index for sub county c, e represents the calculated exposure score for sub county c, a represents the estimated adaptive capacity score for sub county c and, s_c represents the sensitivity score for sub county c. In this study, the LVI-IPCC scale ranging from -1 (least vulnerable) to +1 (most vulnerable) was adopted as developed by Hahn *et al*., (2009).

Table 3.2. LVI major components and subcomponents

Major component	Sub-components	Explanatory notes for sub-components	Units	Data source
Socio-demographic profile	Dependency ratio	Ratio of people aged 15 to 64 years old (inactive population) to people aged 15 to 64 years old (active population)	Ratio	Survey
	Proportion of male/female headed households	If a male household head is absent for more than six months, the female is considered the head of the household.	Percent	Survey
	Average age of male/female head of household	Household heads' average age	1/Years	Survey
	The proportion of households where the head of the household has not attended school	Percentage of households where the head of the household reports having attended 0 years of school	Percent	Survey
	The proportion of households with orphans	The proportion of households with at least one orphan under the age of 18 whose one or both parents have died.	Percent	Survey
Livelihood Strategies	The proportion of households in which no family member works in a different community.	Percentage of households where no family member works and earns a living outside of their community Question is modified to give a positive vulnerability score when a household doesn't have a member working outside the community	Percent	Survey
	Percentage of households whose sole source of income is pastoralism	Percentage of households reporting agriculture as their sole source of income	Percent	Survey
	Average agricultural livelihood diversification index	The inverse of (the number of agricultural livelihood activities reported by a household +1) The livelihood activities considered in this study included crop farming, animal rearing and collecting of natural resources for sale	1/#Livelihoods	Survey
Social Networks	Average receive: Give ratio	The ratio of (the number of types of help received by a household in the previous month +1) to (the number of types of help given to someone else by a household in the previous month +1)	Ratio	Survey
	Average borrow: Lend money ratio	The ratio of a household borrowing money in the previous month to a household lending money in the previous month	Ratio	Survey
	Percentage of households that sought assistance from their local government in the previous 12 months	The percentage of households who reported seeking help from their local government. Question is modified to give a positive vulnerability score when a household seeks help as seeking help is seen as a sign of helplessness which signifies vulnerability	Percent	Survey
Health	Average time to health facility on foot	The average time it takes households to walk to the nearest health facility.	Minutes	Survey

Major component	Sub-components	Explanatory notes for sub-components	Units	Data source
	Percentage of households with a chronically ill family member	Percentage of households with at least one chronically ill member	Percent	Survey
	Percentage of households in which a family member missed work or school in the previous two weeks due to illness	The percentage of households where a member missed work or school in the previous two weeks due to illness.	Percent	Survey
	Average Malaria Exposure*Prevention Index	Months of malaria exposure*owning at least one bed net (with bed net = 0.5, without bed net = 1)	Months*Bed net Indicator	Survey
Food	Percentage of households relying solely on family farm for food	Percentage of households who solely rely on their family farm for food	Percent	Survey
	Average number of months households struggle to find food	Average number of months in a year households struggle with food shortage	Months	Survey
	Average Crop Diversity Index	The inverse of (a household's number of crops grown +1)	1/#Crops	Survey
	Percentage of households that do not save crops	Percentage of households that do not save crops from their harvest	Percent	Survey
	Percentage of households that do not save seeds	Percentage of households that do not save seeds for future seasons	Percent	Survey
Water	Percentage of households reporting a water conflict	Percentage of households reporting the occurrence of water conflicts in their community	Percent	Survey
	Percentage of households that use a natural water source	The proportion of households that get their water from natural sources such as rivers, streams, and traditional river wells.	Percent	Survey
	Average time to water source on foot	Average time households take to reach their primary water source on foot	Minutes	Survey
	Percentage of households without a reliable water supply	Percentage of households reporting that water is not available at their primary water source every day	Percent	Survey
	Inverse of the average amount of water stored per household.	The inverse of (the average number of litres of water stored by each household+1)	1/Litres	Survey
Natural Disasters and Climate Variability	Average number of floods, drought and windstorms in the past six years	Total number of droughts, floods and wind storms reported by households in the past six years	Count	Survey
	Percentage of households that did not receive a warning about impending natural disasters	Percentage of households who did not receive any prior warning about imminent natural disasters in the past six years	Percent	Survey
	Percentage of households affected by recent natural disasters in terms of injury or death	The proportion of households reporting a natural disaster-related death or injury in the previous six years.	Percent	Survey

Major component	Sub-components	Explanatory notes for sub-components	Units	Data source
	Mean standard deviation of monthly average of average maximum daily temperatures (last six years)	The standard deviation of the average daily maximum temperature by month between 2015 and 2020	Celsius	Kenya Meteorological Department
	Mean standard deviation of monthly average of average minimum daily temperatures (last six years)	The standard deviation of the average daily minimum temperature by month between 2015 and 2020	Celsius	Kenya Meteorological Department
	Mean standard deviation of monthly average precipitation (last six years)	The standard deviation of the average monthly precipitation between 2015 and 2020	Millimeters	Kenya Meteorological Department

Source: Adapted from (Hahn *et al*., 2009).

Table 3.3. LVI-IPCC vulnerability contributory factors

Vulnerability contributing factors	Main components
Sensitivity	Food, Health and Water
Exposure	Natural disasters and climate variability
Adaptive capacity	Socio-demographic profile, Social networks and Livelihood strategies

Source: Adapted from Hahn *et al*., (2009).

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Demographic Profile of the Respondents

The survey data for this study was obtained from a sample of 398 households among the Gabbra community in Marsabit County. In the study, representative samples were obtained from North-Horr, Moyale, Marsabit North, Marsabit Central, Marsabit South, Loiyangalani, Sololo sub counties (Table 4.1). According to the results, out of the total sample interviewed, female respondents were 20 percent from North-Horr, 22 percent from Marsabit North, 30 percent from Loiyangalani, 38 percent from Loiyangalani, 38 percent from Sololo, 46 percent in Moyale and, 20 percent from Marsabit Central.

The average age of household heads in North-Horr was found to be 49.52 years, while it is 49.76 years in Marsabit North, 47.96 years in Loiyangalani, 49.38 years in Sololo, 45.06 years in Moyale and, 45.06 years in Marsabit Central. Literary analysis indicates that the majority of the respondents interviewed had primary school education. The mean monthly income for household heads was low in most households. The average monthly income is Ksh.9,980.00 in North-Horr, Ksh.8,931.00 in Marsabit North, KSh.6,350.00 in Loiyangalani, Ksh.6,673.50 in Sololo, Ksh.7,320.00, Ksh. 9470.00 in Marsabit Central and, Ksh. 7698.00 in Marsabit South. Descriptive statistics of the survey data shows varied household sizes across the sub counties are varied. In North-Horr the average household size is 5.24 while it is 5.26 in Marsabit North, 5.18 in Loiyangalani, 5.12 in Sololo, 5.88 in Moyale, 6.32 in Marsabit Central and 6.04 in Marsabit South.

Table 4.1. Demographic profile of survey participants

Sub-County	Variable	Mean	Std. Dev.	Min	Max
North-Horr	Gender	0.2	0.4	0	1
	Age	49.52	14.25	30	82
	Education	0 .32	0.91	0	4
	Monthly income	9980	13862.56	2000	85000
	Household size	5.24	2.45	0	13
Marsabit North	Gender	0 .22	0.42	0	1
	Age	49.76	13.35	29	75
	Education	0.66	1.12	0	4
	Monthly income	8931	8829.71	550	50000
	Household size	5.26	1.77	2	10
Loiyangalani	Gender	0.3	0.46	0	1
	Age	47.96	11.99	27	75
	Education	0.34	0.77	0	3
	Monthly income	6350	4291.91	1200	15000
	Household size	5.18	2.01	2	12
Sololo	Gender	0.38	0.49	0	1
	Age	49.38	14.5	29	92
	Education	0.14	0.5	0	2
	Monthly income	6673.5	5314.74	0	20000
	Household size	5.12	1.96	2	12
Moyale	Gender	0.46	0.5	0	1
	Age	45.06	14.92	21	81
	Education	0.24	0.62	0	2
	Monthly income	7320	5454.67	0	20000
	Household size	5.88	2.13	2	11
Marsabit Central	Gender	0.12	0.33	0	1
	Age	51.7	15.12	20	85
	Education	0.38	0.81	0	3
	Monthly income	9470	8378.62	500	50000
	Household size	6.32	2.74	3	16
Marsabit South	Gender	0.2	0.4	0	1
	Age	51.8	15.47	30	99
	Education	0.18	0.66	0	3
	Monthly income	7698	8102.14	500	50000
	Household size	6.04	2.53	3	13
N= 398					

4.2 Trend Analysis of Rainfall in Marsabit County from 1990 to 2022

The rainfall data was first evaluated for serial correlation using lag-1 autocorrelation at the 5% significance level to ensure that the data was random. In order to offset the effect of serial correlation, the study used the pre-whitening method. The study used Mann–Kendall test and Theil-Sen's slope estimator to analyze the monthly, annual, and seasonal rainfall trends in Marsabit County between 1990 and 2022. Table 4.1 provides analysis of the monthly mean data on precipitation in Marsabit County. The December and January precipitation trends are negative while the months of February to November have positive trends. However, the MK test did not reveal any statistically significant trend ($p \leq 0.05$) for the mean monthly data. However, the results revealed statistically significant ($p \leq 0.05$) and positive trends for Loiyangalani in April, Marsabit North in August, Marsabit South in September, and Marsabit Central in October in the study period. Figure 4.1 confirms MK results through decomposition of additive time series for precipitation in Marsabit County from 1990 to 2022. This includes observed, trend, seasonal and random graphs.

The trend of the mean annual rainfall in Marsabit County, though not statistically significant, has been declining. In the seasonal analysis, it has been revealed that precipitation in both the short-rain and long-rain seasons has been declining. The results compare with reviewed literature that rainfall patterns in Marsabit County have shown a decreasing trend over the years, with prolonged dry spells and erratic rainfall distribution (Wato *et al*., 2022; Galwab, 2023; Gudere *et al*., 2023). Similar findings for Marsabit county have been reported in a study by Galwab *et al*. (2023). The results confirm the unpredictability of precipitation in all the sub-counties in Marsabit County.

The study also established that mean annual precipitation in different sub-counties varied. In Moyale and Sololo, there was a decline in precipitation whereas in Loiyangalani, Marsabit South, Marsabit Central, Marsabit North, and North Horr the rainfall had an increasing trend. However, the only significant trend was observed in Loiyangalani. The variation may be explained the existence of four ecological zones (i.e. III, IV, V & VI) in Marsabit County (Government of Kenya, 2018).

Table 4.1: Trend Analysis of Monthly Mean Precipitation in Marsabit County from 1990 to 2022

AREA		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
County	ACF	-0.278	-0.128	-0.048	-0.308	-0.096	-0.241	-0.126	0.039	0.101	-0.193	-0.325	-0.242
	Zs	-0.139	0.666	0.047	0.945	0.480	1.348	0.000	0.170	1.7199*	0.945	0.542	-0.449
	Qmed	-0.048	0.123	0.039	0.781	0.178	0.133	0.001	0.014	0.147	0.562	0.225	-0.331
Moyale	ACF	-0.168	-0.128	0.030	-0.281	0.039	-0.118	-0.016	-0.211	0.107	-0.314	-0.221	-0.129
	Zs	-0.697	0.418	0.573	0.449	-0.480	-0.604	-1.829*	0.573	0.232	0.759	0.139	-1.224
	Qmed	-0.062	0.088	0.198	0.521	-0.067	-0.046	-0.052	0.008	0.016	0.735	0.093	-0.406
Loiyangalani	ACF	-0.318	-0.206	-0.244	-0.115	0.170	-0.082	0.067	-0.201	0.113	0.205	0.026	-0.287
	Zs	0.201	-0.078	0.852	2.247**	0.139	1.596	1.224	0.573	1.813*	0.294	-0.666	1.193
	Qmed	0.041	-0.012	0.274	1.894	0.054	0.526	0.306	0.130	0.538	0.127	-0.143	0.257
Marsabit South	ACF	-0.257	-0.054	-0.074	-0.233	-0.012	-0.244	-0.135	0.222	0.134	-0.042	-0.240	-0.124
	Zs	-0.047	0.883	-0.914	0.759	0.635	0.356	0.109	-0.604	2.185**	-0.170	-0.263	-0.356
	Qmed	-0.022	0.306	-0.811	1.175	0.313	0.070	0.007	-0.094	0.284	-0.205	-0.187	-0.259
Marsabit Central	ACF	-0.246	-0.069	0.149	-0.165	0.017	-0.199	-0.244	-0.015	-0.001	-0.011	-0.338	-0.111
	Zs	-1.007	0.201	-0.480	0.139	0.976	-0.418	-0.078	-0.217	0.418	1.968**	0.883	-0.914
	Qmed	-0.048	0.015	-3342.000	0.369	0.685	-0.041	-0.003	-0.009	0.020	3.083	1.353	-0.691
Marsabit North	ACF	-0.288	-0.028	-0.248	-0.039	-0.056	0.120	0.123	0.010	-0.050	-0.068	-0.184	-0.275
	Zs	1.100	0.884	0.170	1.255	-0.821	-0.109	0.232	2.340**	0.016	-0.635	-0.480	-0.728
	Qmed	0.114	0.076	0.064	0.888	-0.116	-0.001	0.003	0.033	0.000	-0.041	-0.060	-0.086
Sololo	ACF	-0.138	-0.043	0.000	**-0.419**	-0.076	-0.085	-0.125	-0.062	0.041	-0.201	-0.302	-0.136
	Zs	-5113.000	0.170	0.232	1.6703*	0.759	-1.007	-1.100	0.821	0.511	0.914	0.852	-0.697
	Qmed	-0.043	0.023	0.103	1.488	0.552	-0.054	-0.037	0.052	0.024	0.566	0.533	-0.211
North Horr	ACF	-0.193	-0.119	0.002	-0.271	-0.071	-0.221	0.041	0.122	-0.047	0.203	-0.213	-0.264
	Zs	-0.356	0.170	-0.449	0.139	0.697	0.759	0.263	-1.131	0.542	-1.255	-1.007	-0.047
	Qmed	-845.000	0.027	-0.188	0.092	0.096	0.082	0.047	-0.123	0.034	-0.264	-0.477	-0.024

- ACF = Autocorrelation Coefficient; Z_s = Mann-Kendall trend test; Q_{med} = Theil-Sen's slope
- *** = significant at 1%; ** = significant at 5%; and *= significant at 10%
- The presence of serial correlation is indicated by bold numerals, but it has been successfully eliminated

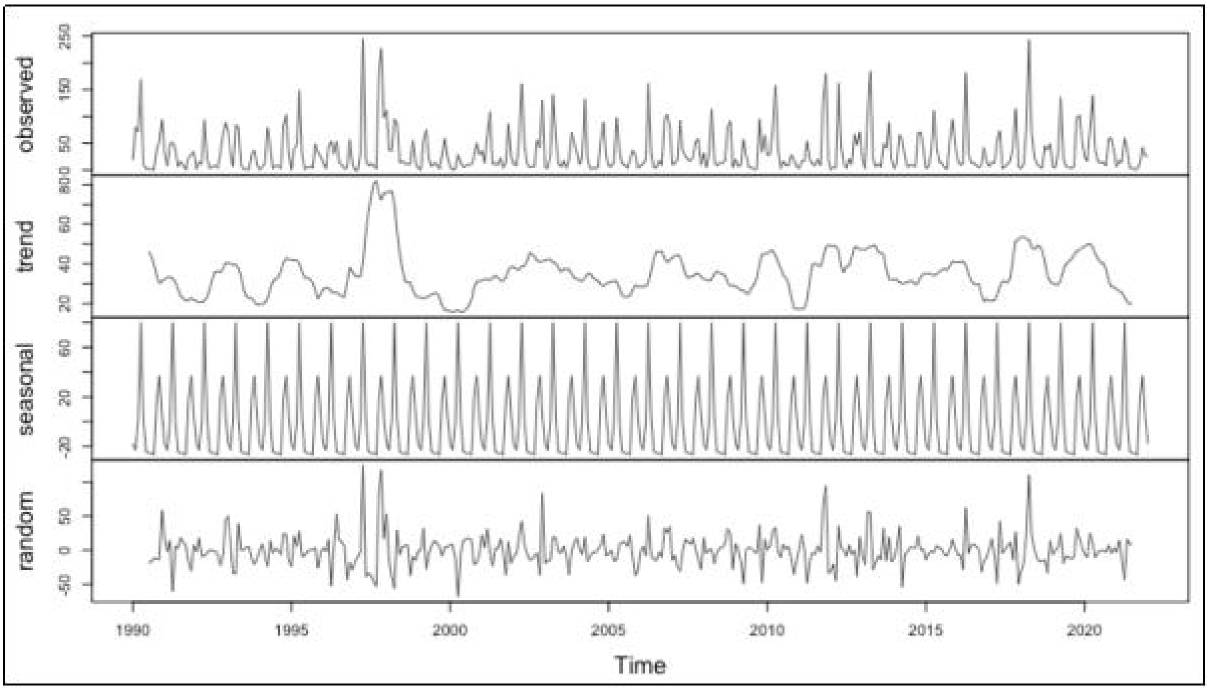

Figure 4.1: Decomposition of Additive Time Series for Precipitation in Marsabit County from 1990 to 2022

4.3 Trend Analysis of Maximum Temperature in Marsabit County from 1990 to 2022

The maximum temperature data was first evaluated for serial correlation using lag-1 autocorrelation at the 5% significance level to ensure that the data was random. In order to offset the effect of serial correlation, the study used the pre-whitening method. The analysis of maximum temperature data for Marsabit County showed statistically significant ($p \leq 0.05$) warming in July, September and December from 1990 to 2022 (Table 4.2). In Moyale, the statistically significant ($p \leq 0.05$) warming was observed in August. The months observed to have statistically significant ($p \leq 0.05$) increase in temperature in Marsabit South were January, August, September, and December. In Marsabit Central, the months of January, February, March, September, November and December experienced statistically significant warming. In North Horr, the months of January, July, September and December experienced statistically significant ($p \leq 0.05$) increase in temperature in the study period. Similar results were obtained in Figure 4.2, which shows an increasing maximum temperature trend in Marsabit County from 1990 to 2022.

Table 4.2: Trend Analysis of Monthly Mean Maximum Temperature in Marsabit County from 1990 to 2022

AREA		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
County	ACF	0.028	-0.065	-0.104	**-0.388**	-0.020	-0.170	-0.061	0.087	0.196	-0.124	0.057	**-0.471**
	Zs	1.379	0.604	1.379	0.114	-0.449	1.410	1.9368**	1.7199*	2.681***	-0.387	0.325	2.319**
	Qmed	0.028	0.008	0.030	0.004	-0.002	0.024	0.025	0.023	0.018	-0.005	0.006	0.050
Moyale	ACF	0.060	-0.030	-0.071	-0.222	-0.079	0.062	0.075	**0.451**	0.268	-0.124	0.215	-0.256
	Zs	0.821	0.139	1.503	0.573	0.852	0.945	1.627	3.033***	1.844*	-0.418	0.573	1.286
	Qmed	0.024	0.002	0.034	0.007	0.016	0.018	0.032	0.034	0.020	-0.008	0.013	0.040
Loiyangalani	ACF	0.176	**0.374**	-0.047	-0.108	0.066	-0.238	0.205	-0.015	0.107	-0.018	-0.074	-0.215
	Zs	0.480	-0.568	0.047	0.294	-0.139	1.100	1.503	0.434	-1.426	-0.883	-1.255	0.016
	Qmed	0.004	-0.011	0.005	0.012	-0.007	0.047	0.043	0.014	-0.024	-0.022	-0.037	0.001
Marsabit South	ACF	0.285	0.164	-0.050	-0.340	0.105	-0.064	0.043	0.220	0.291	0.120	0.074	-0.032
	Zs	2.247**	0.170	1.162	0.170	-1.162	0.759	1.007	2.959***	2.634***	0.666	1.224	2.990***
	Qmed	0.035	0.003	0.029	0.007	-0.023	0.011	0.023	0.044	0.029	0.012	0.018	0.046
Marsabit Central	ACF	0.092	0.041	-0.035	-0.085	0.073	0.188	**0.445**	**0.418**	**0.691**	0.092	0.159	0.011
	Zs	2.928***	4.013***	2.743***	1.6889*	1.472	1.7509*	1.346	1.131	1.962**	0.759	2.402**	3.580***
	Qmed	0.070	0.059	0.074	0.052	0.036	0.035	0.040	0.020	0.050	0.014	0.043	0.083
Marsabit North	ACF	0.082	-0.042	-0.085	-0.243	0.093	-0.065	0.046	0.025	0.236	**0.365**	0.038	**-0.487**
	Zs	1.224	0.201	0.217	-1.007	-1.348	0.558	0.294	1.705*	1.302	-2.509**	-1.162	-0.049
	Qmed	0.031	0.006	0.006	-0.023	-0.029	0.006	0.002	0.017	0.013	-0.028	-0.022	-0.001
Sololo	ACF	-0.130	-0.073	-0.034	**-0.409**	0.041	0.095	0.081	0.262	**0.519**	-0.229	0.342	**-0.417**
	Zs	0.790	-0.449	1.038	0.438	1.131	0.170	0.604	1.751*	0.860	-0.403	0.434	1.249
	Qmed	0.022	-0.009	0.029	0.007	0.023	0.006	0.010	0.032	0.011	-0.004	0.008	0.029
North Horr	ACF	0.133	-0.065	-0.185	-0.326	-0.123	-0.020	-0.029	**0.570**	**0.365**	-0.245	0.086	-0.175
	Zs	2.339**	1.875*	1.503	0.016	-0.728	1.348	2.0608**	0.924	2.903***	0.016	0.403	2.681***
	Qmed	0.038	0.027	0.028	0.000	-0.013	0.031	0.029	0.013	0.031	0.000	0.007	0.051

- ACF = Autocorrelation Coefficient; Z_s = Mann-Kendall trend test; Q_{med} = Theil-Sen's slope
- *** = significant at 1%; ** = significant at 5%; and *= significant at 10%
- The presence of serial correlation is indicated by bold numerals, but it has been successfully eliminated

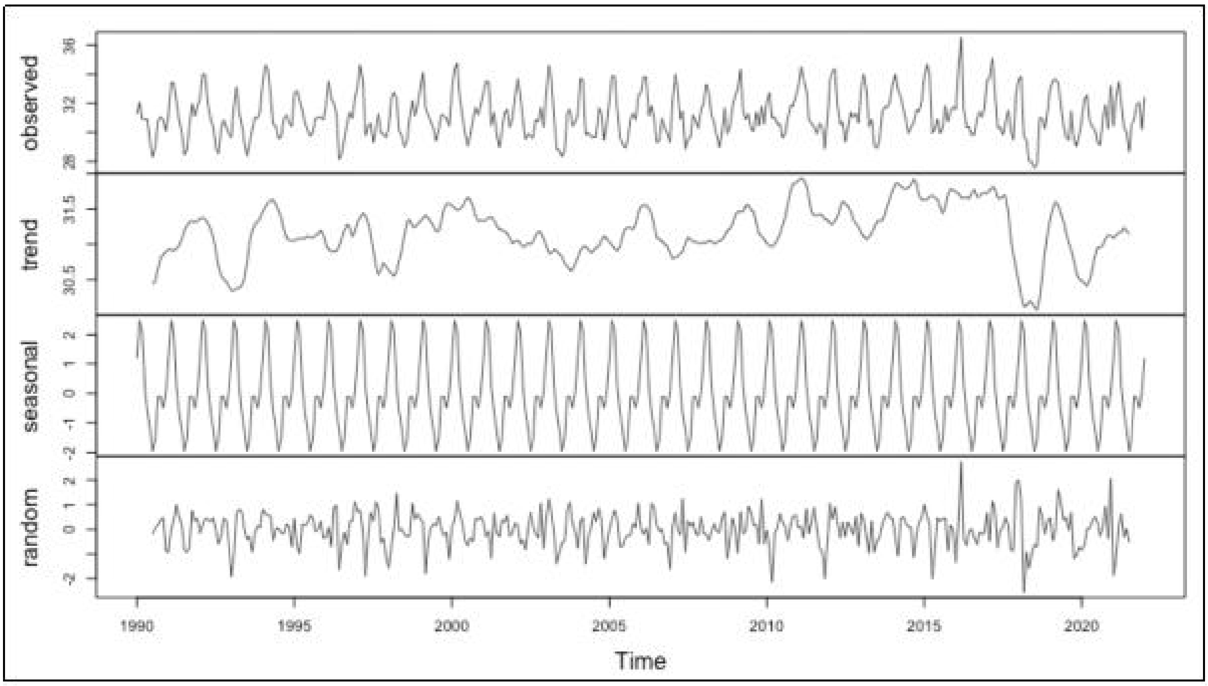

Figure 4.2: Decomposition of Additive Time Series for Maximum Temperature in Marsabit County from 1990 to 2022

4.4 Trend Analysis of Minimum Temperature in Marsabit County from 1990 to 2022

The data on minimum temperature was first evaluated for serial correlation using lag-1 autocorrelation at the 5% significance level to ensure that the data was random. In order to offset the effect of serial correlation, the study used the pre-whitening method. The trend analysis of monthly mean minimum temperature in Marsabit County from 1990 to 2022 is provided in Table 4.3. The analysis reveals that the increase in minimum temperature was statistically significant ($p \leq 0.05$) in August, September and October. In Moyale, the month of July had a statistically significant ($p \leq 0.05$) increase in minimum temperature. The months of September and October were found to have significantly ($p \leq 0.05$) warming in Loiyangalani and Marsabit South. In Marsabit Central the minimum temperature was observed to be significantly ($p \leq 0.05$) increasing in the months of February, March, April and December. The months of July, August, September and October were observed to have an increasing minimum temperature in Sololo from 1990 to 2022. In Figure 4.3, similar results were obtained using the decomposition of additive time series for minimum temperature in Marsabit County from 1990 to 2022.

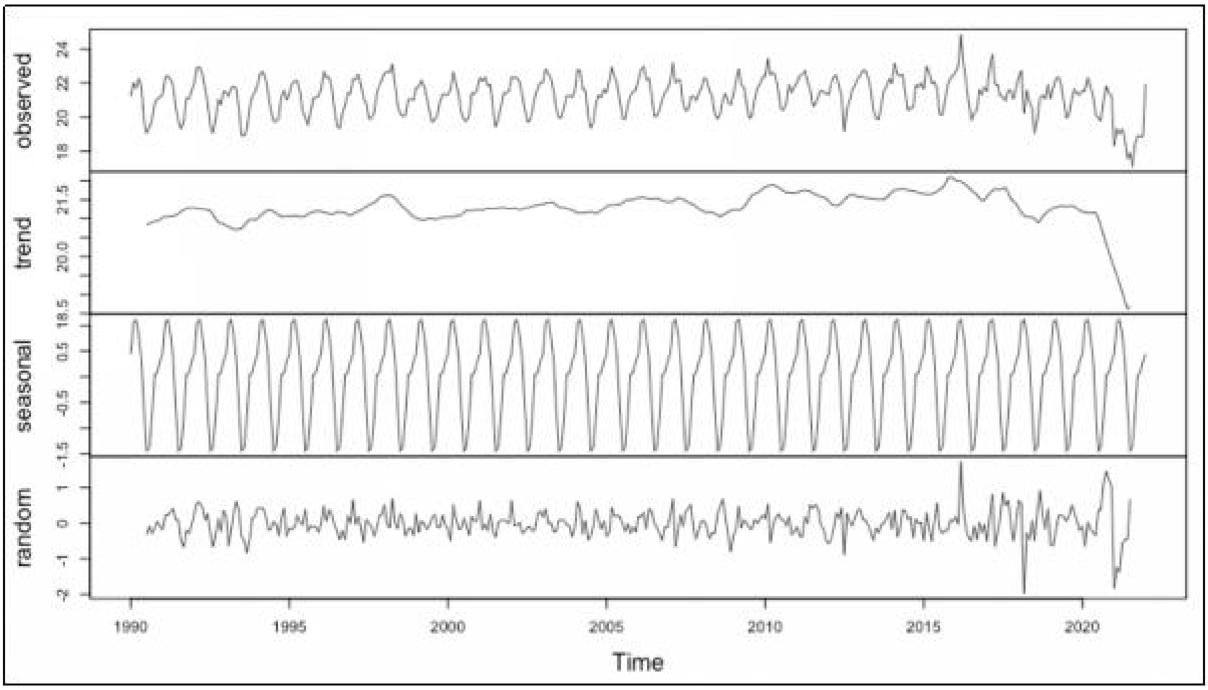

Figure 4.3: Decomposition of Additive Time Series for Minimum Temperature in Marsabit County from 1990 to 2022

Table 4.3: Trend Analysis of Monthly Mean Minimum Temperature in Marsabit County from 1990 to 2022

AREA		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	ACF	-0.027	0.076	-0.053	-0.163	-0.049	0.223	0.001	**0.350**	**0.378**	0.151	0.067	-0.048
County	Zs	0.449	1.069	0.914	0.002	1.224	1.441	1.317	2.222^{**}	3.357^{***}	3.207^{***}	1.007	1.813^{*}
	Qmed	0.003	0.015	0.010	0.000	0.011	0.015	0.011	0.022	0.024	0.024	0.008	0.015
	ACF	0.021	0.165	-0.138	-0.230	-0.115	0.228	0.167	**0.548**	**0.364**	0.146	**0.427**	0.114
Moyale	Zs	-0.465	1.534	1.069	-0.573	1.317	1.472	2.4636^{**}	1.184	0.470	0.759	-0.243	1.720^{*}
	Qmed	-0.004	0.016	0.013	-0.007	0.012	0.016	0.025	0.010	0.005	0.006	-0.002	0.020
	ACF	-0.065	-0.090	-0.059	-0.234	-0.189	0.030	-0.152	0.088	0.124	0.006	-0.061	-0.123
Loiyangalani	Zs	0.000	0.480	0.139	0.387	0.310	0.449	0.573	1.271	3.424^{***}	2.216^{**}	0.263	0.047
	Qmed	0.000	0.007	0.004	0.005	0.004	0.003	0.008	0.013	0.051	0.025	0.003	0.002
	ACF	0.137	**0.366**	0.271	**0.376**	**0.362**	**0.474**	**0.369**	**0.468**	**0.440**	0.269	0.068	0.000
Marsabit South	Zs	0.000	0.114	0.170	-0.600	-0.049	-0.373	-0.341	0.178	3.033^{***}	2.495^{***}	0.992	1.038
	Qmed	0.000	0.004	0.003	-0.009	-0.001	-0.005	-0.009	0.005	0.037	0.029	0.010	0.010
	ACF	**0.483**	**0.387**	0.173	0.341	**0.372**	**0.479**	**0.755**	**0.756**	**0.770**	**0.733**	**0.643**	**0.605**
Marsabit Central	Zs	1.022	2.1244^{**}	3.920^{***}	2.2777^{**}	1.8649^{*}	1.7027^{*}	0.730	1.703^{*}	1.703^{*}	1.443	1.216	2.351^{**}
	Qmed	0.016	0.030	0.042	0.034	0.026	0.021	0.013	0.020	0.020	0.020	0.020	0.029
	ACF	0.218	**0.348**	0.193	0.251	0.256	**0.463**	0.298	**0.452**	**0.441**	**0.454**	**0.542**	0.285
Marsabit North	Zs	0.263	-0.470	-0.325	-1.286	-0.511	-0.535	0.170	1.119	0.665	-0.568	-1.119	0.279
	Qmed	0.006	-0.013	-0.010	-0.022	-0.006	-0.009	0.004	0.015	0.008	-0.006	-0.014	0.004
	ACF	0.090	0.082	-0.230	-0.236	-0.194	0.137	0.194	**0.349**	0.284	0.015	0.051	-0.136
Sololo	Zs	-0.542	1.255	0.883	0.325	1.6269^{*}	1.302	2.3244^{**}	2.643^{***}	1.999^{**}	2.805^{***}	0.573	1.720^{*}
	Qmed	-0.010	0.019	0.019	0.005	0.018	0.018	0.026	0.028	0.020	0.019	0.006	0.021
	ACF	0.209	0.237	0.293	0.321	0.304	**0.381**	0.190	**0.366**	**0.411**	**0.419**	**0.399**	0.247
North Horr	Zs	0.372	0.976	0.604	-0.682	0.418	-0.146	-0.201	0.730	0.957	0.211	-0.470	0.852
	Qmed	0.006	0.014	0.010	-0.007	0.003	-0.002	-0.004	0.016	0.011	0.002	-0.007	0.014

- ACF = Autocorrelation Coefficient; Z_s = Mann-Kendall trend test; Q_{med} = Theil-Sen's slope
- *** = significant at 1%; ** = significant at 5%; and *= significant at 10%
- The presence of serial correlation is indicated by bold numerals, but it has been successfully eliminated

4.5 Short Rain and Long Rain Seasons in Marsabit County from 1990 to 2022

The precipitation and temperature data for Marsabit County was analysed for trends during the short-rain and long-rain seasons. Table 4.4 shows statistically significant ($p \leq 0.05$) increase in minimum temperature during the long-rain season. However, precipitation and maximum temperature during the season were found to be decreasing albeit not significantly. The results show non-significant decline in precipitation during the short-rain season. Similar results were observed for the maximum and minimum temperature during the season.

The maximum temperature for Moyale was observed to have increased significantly ($p \leq 0.05$) during the long-rain season. The results show that the maximum temperature in Marsabit South had significantly ($p \leq 0.05$) increased during the short-rain season in Marsabit South. The Marsabit Central experienced a significant increase in maximum and minimum temperature during the long-rain season as well as increased maximum temperature during the short-rain season. The minimum temperature in both short-and long-rain seasons had significantly ($p \leq 0.05$) increased from 1990 to 2022.

Table 4.4: Trend Analysis of Short-Rain and Long-Rain Seasons in Marsabit County from 1990 to 2022

AREA		LONG-RAIN SEASON (March-April-May)			SHORT-RAIN SEASON (October-November-December)		
	Test	Precipitation	Maximum Temperature	Minimum Temperature	Precipitation	Maximum Temperature	Minimum Temperature
County	ACF	-0.188	-0.307	0.051***	**-0.376**	-0.341	-0.098
	Zs	0.573	0.945	2.743	0.243	1.317	1.472
	Qmed	0.242	0.009	0.015	0.097	0.017	0.011
Moyale	ACF	-0.219	-0.210	-0.176	-0.324	-0.184	**0.415**
	Zs	-0.016	2.061**	1.379	-0.016	1.286	0.243
	Qmed	-0.013	0.025	0.010	-0.033	0.013	0.002
Loiyangalani	ACF	-0.219	-0.076	-0.192	-0.324	-0.098	-0.075
	Zs	-0.016	0.511	0.232	-0.016	-1.379	1.627
	Qmed	-0.013	0.010	0.001	-0.033	-0.035	0.014
Marsabit South	ACF	-0.136	-0.188	**0.403**	-0.235	0.051	0.142
	Zs	0.449	0.635	-0.211	-0.449	2.2467**	1.534
	Qmed	0.343	0.014	-0.002	-0.299	0.025	0.017
Marsabit Central	ACF	-0.050	-0.066	0.302	-0.269	0.151	**0.700**
	Zs	0.047	2.526***	3.579***	0.945	2.959***	1.443
	Qmed	0.047	0.056	0.040	1.036	0.044	0.016
Marsabit North	ACF	-0.083	-0.081	0.290	-0.296	-0.066	**0.478**
	Zs	0.263	-0.511	-0.170	-0.728	-1.410	-0.470
	Qmed	0.079	-0.019	-0.004	-0.109	-0.019	-0.005
Sololo	ACF	-0.114	-0.215	-0.255	-0.300	-0.186	-0.037
	Zs	0.945	1.7508*	1.875**	0.821	0.511	2.123**
	Qmed	0.405	0.029	0.015	0.334	0.011	0.016
North Horr	ACF	-0.209	**-0.391**	0.324	-0.280	**-0.355**	0.368
	Zs	-0.356	0.114	0.697	-0.790	1.833*	0.049
	Qmed	-0.080	0.005	0.009	-0.243	0.022	0.000

- ACF = Autocorrelation Coefficient; Z_s = Mann-Kendall trend test; Q_{med} = Theil-Sen's slope
- *** = significant at 1%; ** = significant at 5%; and *= significant at 10%
- The presence of serial correlation is indicated by bold numerals, but it has been successfully eliminated

4.6 Trend Analysis of Mean Annual Precipitation and Temperature in Marsabit County from 1990 to 2022

The trend analysis was conducted for mean annual precipitation, maximum and minimum temperature (Table 4.5). According to the results, the mean annual maximum and minimum temperature for Marsabit County were found to be significantly ($p \leq 0.05$) increasing while mean annual precipitation was declining, though not significantly, in the study period. In Moyale, the mean annual maximum and minimum temperature were observed to have significantly ($p \leq 0.05$) increased. The mean annual precipitation and minimum temperature have significantly ($p \leq 0.05$) increased in Loiyangalani, Marsabit South, Marsabit Central, North Horr have also experienced a statistically significant ($p \leq 0.05$) increase in mean annual maximum temperature from 1990 to 2022. The mean annual maximum and minimum temperature were also found to have significantly increased in Sololo during the study period.

There has been a significant upward trend in mean annual maximum and minimum temperature in Marsabit County. The literature on climate change in the study area confirms the findings that the climate in the county is warming (County Government of Marsabit, 2023; Gudere *et al*., 2023). Other studies show a shift in rainfall patterns, temperature, and wind distribution in the region over the past few decades (Cuní-Sanchez *et al*., 2018).

Table 4.5: Trend Analysis of Annual Mean Precipitation and Temperature in Marsabit County from 1990 to 2022

Area	Precipitation			Maximum Temperature			Minimum Temperature		
	ACF	Zs	Qmed	ACF	Zs	Qmed	ACF	Zs	Qmed
County	-0.014	0.852	0.162	0.074	2.588***	0.018	0.095	3.083***	0.020
Moyale	-0.162	-0.139	-0.032	0.237	2.588***	0.022	0.308	2.619***	0.016
Loiyangalani	0.245	2.402**	0.553	0.276	0.201	0.003	-0.083	2.123**	0.013
Marsabit South	0.136	-0.232	-0.079	0.261	2.247**	0.021	**0.449**	0.568	0.007
Marsabit Central	0.032	0.635	0.200	0.310	3.827***	0.047	**0.707**	1.476	0.011
Marsabit North	0.019	-0.387	-0.051	0.235	0.418	0.005	**0.461**	0.957	0.003
Sololo	-0.042	0.883	0.173	0.248	1.937**	0.024	0.009	3.083***	0.019
North Horr	0.128	-1.162	-0.194	-0.043	2.526***	0.025	**0.387**	1.087	0.007

- ACF = Autocorrelation Coefficient; Z_s = Mann-Kendall trend test; Q_{med} = Theil-Sen's slope
- *** = significant at 1%; ** = significant at 5%; and *= significant at 10%
- The presence of serial correlation is indicated by bold numerals, but it has been successfully eliminated

4.7 Perceptions and impacts and adaptation to climate change among Gabbra pastoralists' of Marsabit County, Kenya

4.7.1 Gabbra community perceptions on climate change

This study found that a large number (over 90%) of Gabbra pastoralists interviewed reported occurrence of climate change and which they perceived through disruptions of their normal socio-economic activities and lifestyles. In all sub-locations surveyed (Fig 4.6) there was general concurrence on climate change perceptions, with most parameters being similar, except in areas with unique features such as wetlands or extensive plains. Of great concern to the Gabbra was rainfall and temperature changes as both affected availability of water and pasture conditions, which support livestock and which are central to their livelihoods. Similarly, studies (Tamene *et al*., 2023; Shibru, *et al*. 2023) in other dryland areas occupied pastoralists have shown that rising minimum and maximum temperature and the erratic nature of rainfall has undermined the availability of pasture and water resources, especially during drought years resulting in the prevalence of livestock diseases.

The Gabbra pastoralists perceived extreme events or indicators associated directly with livelihood activities such as crop failures, livestock loss (Plate 4.1), dried up water sources, sand storms (Plate 4.2) during droughts among others as most suppressing. These perceptions on climate change among the Gabbra were noted to be complemented by existing indigenous knowledge of the Gabbra people, and which they have used over the years to help them cope with consequential socio-economic disruptions. This is so since Knowledge and perceptions of weather and climate change can influence individual and community strategies to reduce their vulnerability to climate change (Filho et al., 2022). In the context of the Gabbra community the study established that they have intertwined weather and climatic knowledge systems into their customary lifestyles and livelihood systems and which are imperative in adaptation actions.

Plate 4.1 Livestock loss among the Gabbra pastoralists in North Horr, Marsabit County
Source: Field data, 2024

Plate 4.2 Sandstorm in North Horr, Marsabit County
Source: Field data, 2024

Table 4.6 Gabbra community Perceptions on Climate

Perceptions-Indicators to climate change	Sub-county observed	Percentage (%)
Decreasing rainfall trends	All Sub-counties	100.0
Unpredictability of rainfall season	All Sub-counties	100.0
Longer periods of drought	All Sub-counties	100.0
Deterioration of pastures and water sources	All Sub-counties	100.0
Extremely cold nights	North Horr, Moyale, and Sololo.	42.9
Extremely hot days	Loiyangalani, Marsabit South, Marsabit Central, Marsabit North, North Horr,	71.4
Drying up of wetlands	Marsabit Central	14.3
Reduced accuracy in predicting rains using indigenous knowledge	All counties	100.0
Climate induced food shortage	All counties	100.0

The Gabbra Pastoralists and who were the key respondents in this study brought forth a number of climatic experiences and observations which they perceived to indicate climate change occurrences in their area. Most of the indicators related to rainfall changes while others were on temperature, wind and fog conditions. These indicators when subjected to Likert-scale weighting (Fig. 4.7) showed high levels of support and were therefore clear evidence of climate change among the community. As an example taking two contrasting indicators in the graph (Fig.4.4) namely (i) increasing temperatures in dry season was supported by 80.2% of the respondents who strongly agreed and 18.71% who agreed. (ii) An indicator such as "early onset of rainfall" was "highly disagreed" upon (77.3%) and disagreed by (22.33%). These parameters reported by Gabbra pastoralists indicate climate change but through differing perceptions. Such similar parameters have been observed among pastoral communities of northern Tanzania (Kimaro *et al*., 2018), where climate changes perceptions have been reported to include more erratic and reduced amounts of rainfall, rise in temperature and prolonged and frequent periods of drought.

Table: 4.7 Perception Weighting on some climate change indicators identified by Gabbra Pastoralists

Perceptions	**Strongly agree (%)**	**Agree (%)**	***Unaware* (%)**	***Disagree* (%)**	**Strongly disagree (%)**
Increased temperature in dry season	80.72	18.71	-	-	0.61
Increased variability of rainfall	55.83	29.05	15.14	-	-
Early onset of rainfall	0.41	22.33			77.3
Late onset of rainfall	28.72	22.62	5.83	42.92	-
Rain Season has shortened	31.6	42.91	25.52	-	-
Delay in rains onset and ends early	53.23	30.01	0.32	16.5	-
Rainfall has remained the same	0.21	0.06	2.9	18.51	78.32
Rainfall has increased	0.32	0.04	41.62	58.02	
More dry spells	37.09	30.32	32.51	0.11	
Periods of no rainfall have widened	70.21	26.31	1.13	2.11	
Foggy days have become fewer	51.22	31.02	16.62	1.22	
Extreme droughts have increased	72.92	23.43	0.01	-	2.76
Rainfall has decreased	65.42	26.45	0.64	1.42	0.10
Increased temperatures	53.33	41.03	-	0.64	5.02
Rainfall amounts have decreased	70.95	19.67	9.47		
Rainfall ending early	*41.29*	*39.03*	-	*19.67*	

Other important parameters on climate change perception identified by Gabbra were on changes on pasture grass, number of foggy days and wind occurrences in the dry season. Variation in rainfall and temperature have been known to be key causes of various impacts on livelihoods of pastoralists as well as increase their vulnerability (Regina-Hoi 2022). A thorough understanding of these climate change indicators was noted to be very important in guiding the socio-economics and livelihoods of the Gabbra. How individuals understand or perceive climate change is important in the development of policies that aim to address the problem and their willingness to change behavior (Sraku-Lartey *et al*., 2020).

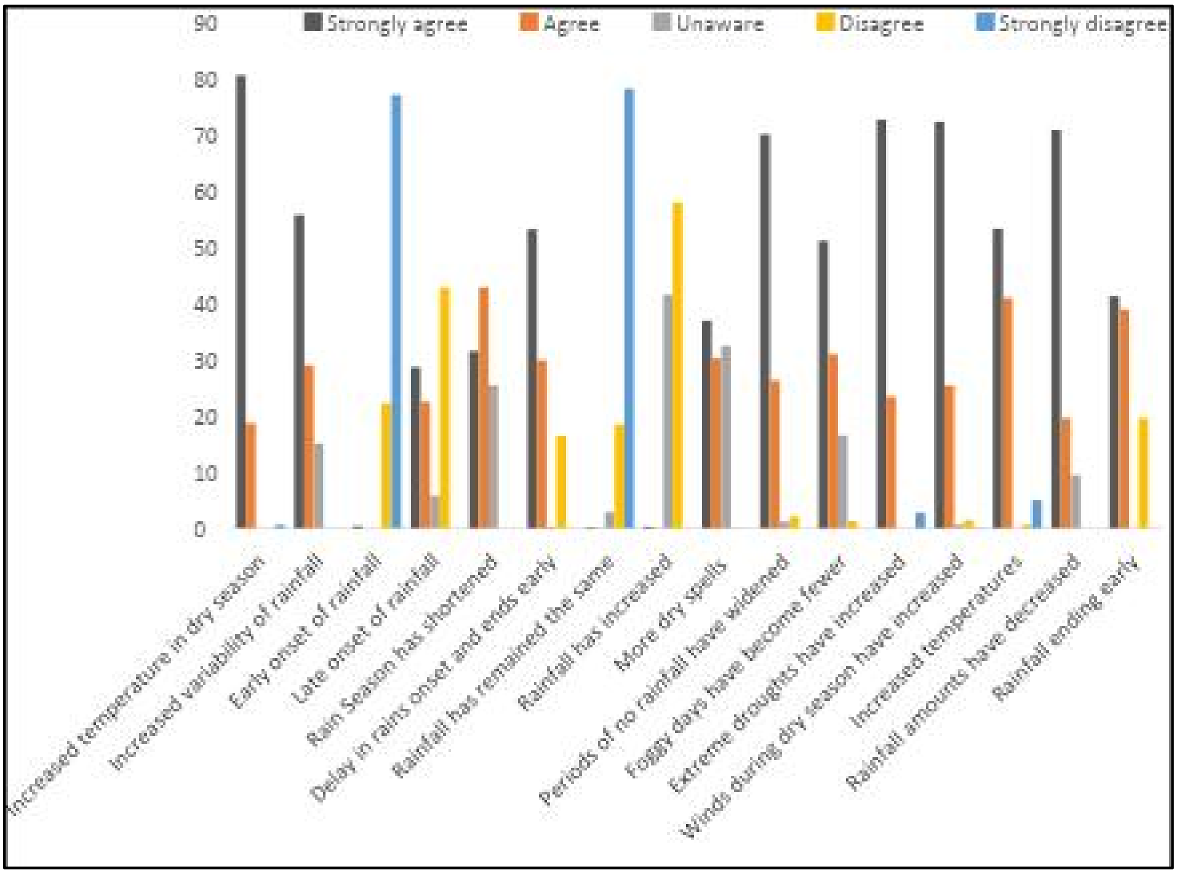

Figure 4.4 Some parameters perceived as indicators of climate change by Gabbra Pastoralists

4.7.2 Perceptions on climate change Impacts among the Gabbra pastoralists

A number of impact parameters were identified by Gabbra covering various climatic factors of rainfall, temperature, fog, winds and related elements and how climate change impacted on them, and consequently on the Gabbra landscapes and pastoral-based socio-economics. Results showed overwhelming negative impacts on these elements especially rainfall anomalies with most reflecting decreases which result in droughts, loss of pastures, water scarcity and subsequently livestock deterioration and deaths. Respondents also reported that occasionally, very heavy rainfall would be experienced and for very short durations of 1-3 weeks during which time severe floods would occur leading to the Gabbra pastoralists incurring huge livestock losses (Plate 4.3). Impact detections parameters included delayed onset, delayed ending of rains, decreased rainfall amounts, very short rain, and more dry spells among others.

Plate 4.3 Flooding in Marsabit North in North Horr, Marsabit County
Source: Field data, 2024

The Gabbra have been experiencing climate change impacts and are able to identify those factors that affect them either directly or indirectly. These factors range from droughts occasioned by scarcity of rains to floods which conversely are due very intense rains, most which fall very heavily over short durations of time. climate change factors. Between extremes of droughts and floods are related impacts either related to weather, their local ecosystems or to socio-economic activities. The respondents were able to identify a few of the impacts which include livestock losses due to drought floods, frequent crop failures, food insecurity among others (Table 4.8). These impacts were found to be interlinked in one way or another. Respondents reported that lack of rains would often lead to prolonged droughts, water scarcity and loss of pastures which may lead even to conflicts and climate induced migration (Plate 4.4). The extent of impact of climate change upon the Gabbra community is dependent upon many factors including how the impacting variables are perceived, other linking factors, magnitude of impact and shifts in the factors, and community vulnerability factors among others. Similar results were obtained in other related studies (e.g., Mekuyie & Mulu, 2021 and Ayele, 2020).

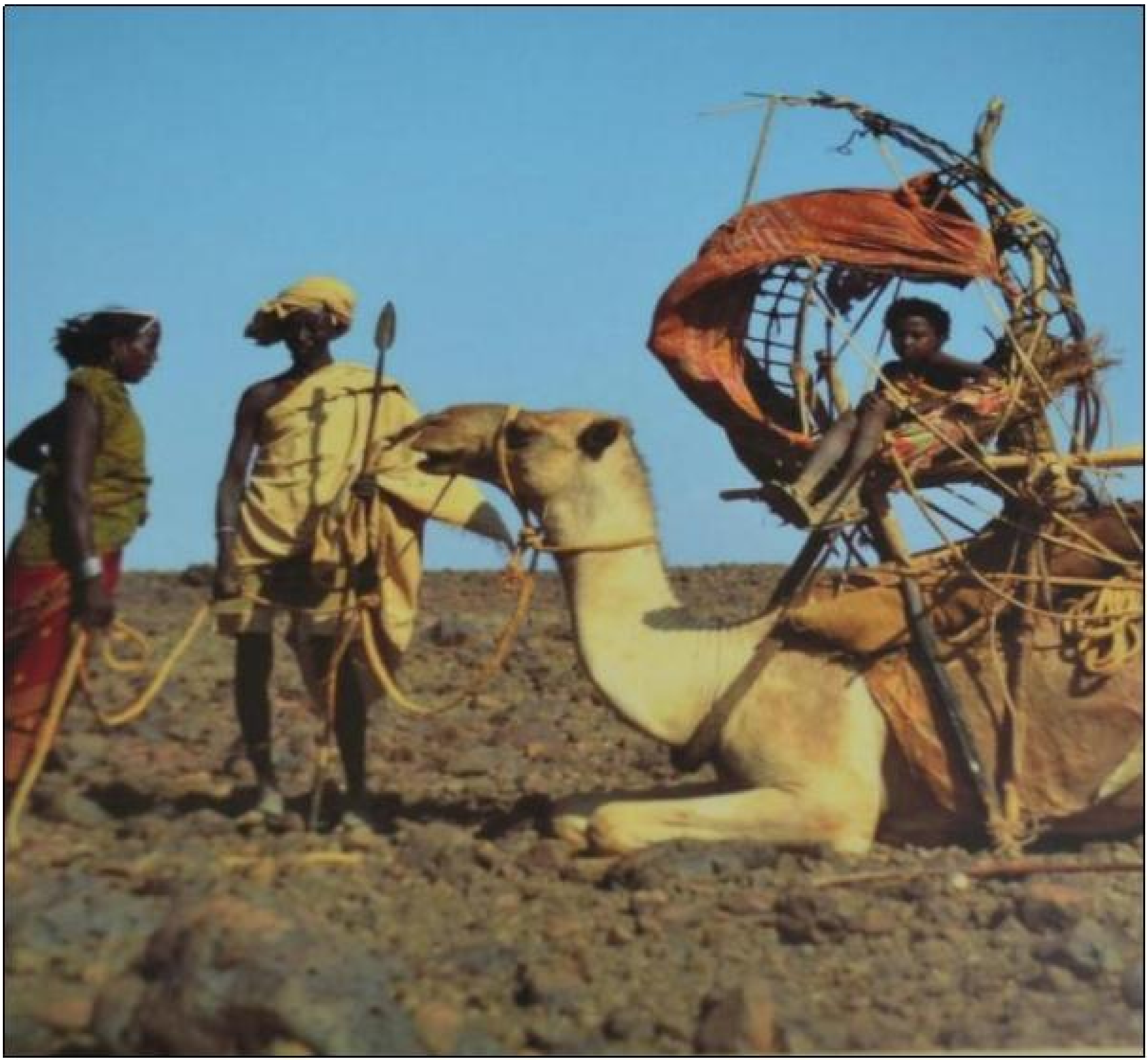

Plate 4.4 Climate induced migration in North Horr, Marsabit County
Source: Field data, 2024

Table 4.8 Perceptions on climate change impacts

Climate Change Impacts	Strongly Agree	Agreed	Unaware	Disagree	Strongly Disagree
Increased incidences of diseases	78.06	5.48	16.12	0.32	0
Increased reliance on food aid	85.8	8.7	5.16	0.3	0
Frequent crop failure	73.87	12.58	10.64	2.58	0.32
Livestock loss	86.77	11.29	1.62	0.32	0
Weather pattern changes	85.46	13.2	1.31	0	0
Livestock pasture declining	84.51	14.19	1.29	0	0
Reduced crop and livestock production	81.29	15.48	2.9	0.32	0
Food insecurity	86.13	12.58	0.96	0.3	0
Severe loss of pasture grass and other	82.25	15.77	0.61	0.32	0.64
Severe water scarcity	76.12	5.48	14.19	3.22	0.97
Out migration of human and livestock	78.39	17.42	0.93	0.63	2.56
Climate change related resource conflicts	80.64	17.09	0.13	0.32	1.82
Severe droughts	83.23	16.13	0.32	0.33	0
Severe flooding	70.03	29.32	0.62	0.03	0

When the identified impacts were weighted using a 5-point Likert-scale over 70 % of the respondents strongly agreed on each one of them (Fig 4.8). The key identified key impacts to climate change include: increased incidences of diseases, increased reliance on food aid (Plate 4.5), frequent crop failure, livestock loss, weather pattern changes, livestock pasture declining, reduced crop and livestock production, food insecurity, severe loss of pasture grass and other, severe water scarcity, out migration of human and livestock, climate change related resource conflicts, severe droughts, and severe flooding. Adapting to these factors was cited as a major challenge largely due their unpredictable nature of their occurrence and severity levels. The Gabbra community however, do make efforts to cope with the impacts including integrating their indigenous knowledge in measures they undertake (Dejene and Yetebarek, 2022).

Plate 4.5 Relief food to Gabbra community in Maikona, Marsabit County

Source: Author, 2024

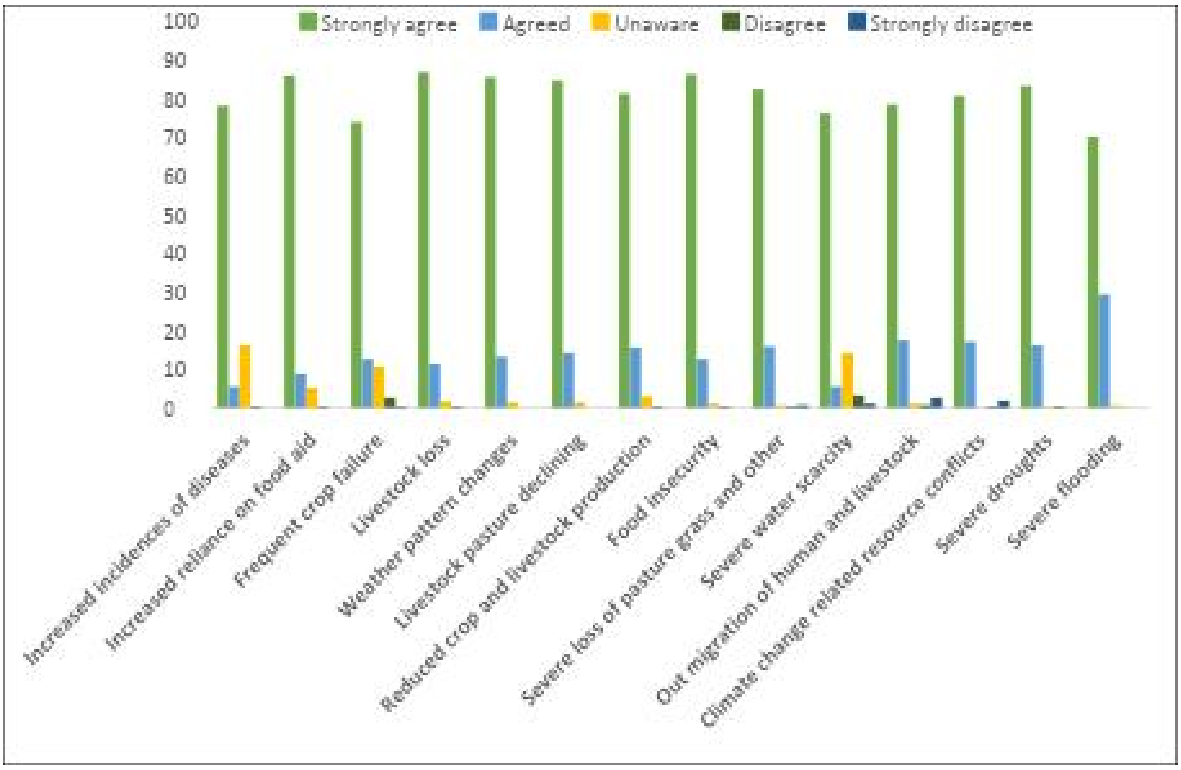

Figure 4.5 Graph showing percentage of acceptability on occurrence of various climate change impact factors

4.7.3 Adaptation Strategies to climate change

Pastoralists in Africa face various climate change challenges that suppress their livelihoods and constrain their ability to adapt to fluctuations in the external environment (FU, 2022). Adaptation strategies reported among the Gabbra pastoralists were centered around livestock production, crop production and soil. The key adaptation strategies identified in livestock production include: destocking (54.84%), separating males from females (36.77%), migration and herd splitting (3.54%), and reliance on fodder aid (4.83%). The strategies for crop production were: reduce farm size (14.19%), drought resistant crops (28.71%), early planting (10.0%), crop diversification (16.13%), and plant early maturing crops (30.97%). With regard to soil management, the identified soil management strategies are: crop rotation (11.11%), using manure (66.67%), and mulching (17.78%). The major reasons for reduction in fam size for the Gabbra pastoralists could be due to poor performance or quality of the technology or variety, government policies, technical constraints, labour shortages or financial constraints (Acevedo *et al.*, 2020)

Table 4.9 Adaptation strategies to climate change undertaken by Gabbra pastoralists

Category	**Strategy**	**Frequency**	**Percentage**
	Reduce Farm size	12	14.19
	Drought Resistant Crops	25	28.71
	Early Planting	9	10.00
Crop Production	Crop Diversification	14	16.13
	Plant Early Maturing Crops	27	30.97
		88	**100.00**
	Destocking	145	54.84
Livestock Production	Separating Males & Females	97	36.77
	Migration & Heard Splitting	9	3.54
	Reliance on Fodder Aid	13	4.83
		265	**100.00**
	Crop Rotation	5	11.11
	Using Manure	30	66.67
Soil Conservation	Mulching	8	17.78
		45	**100.00**

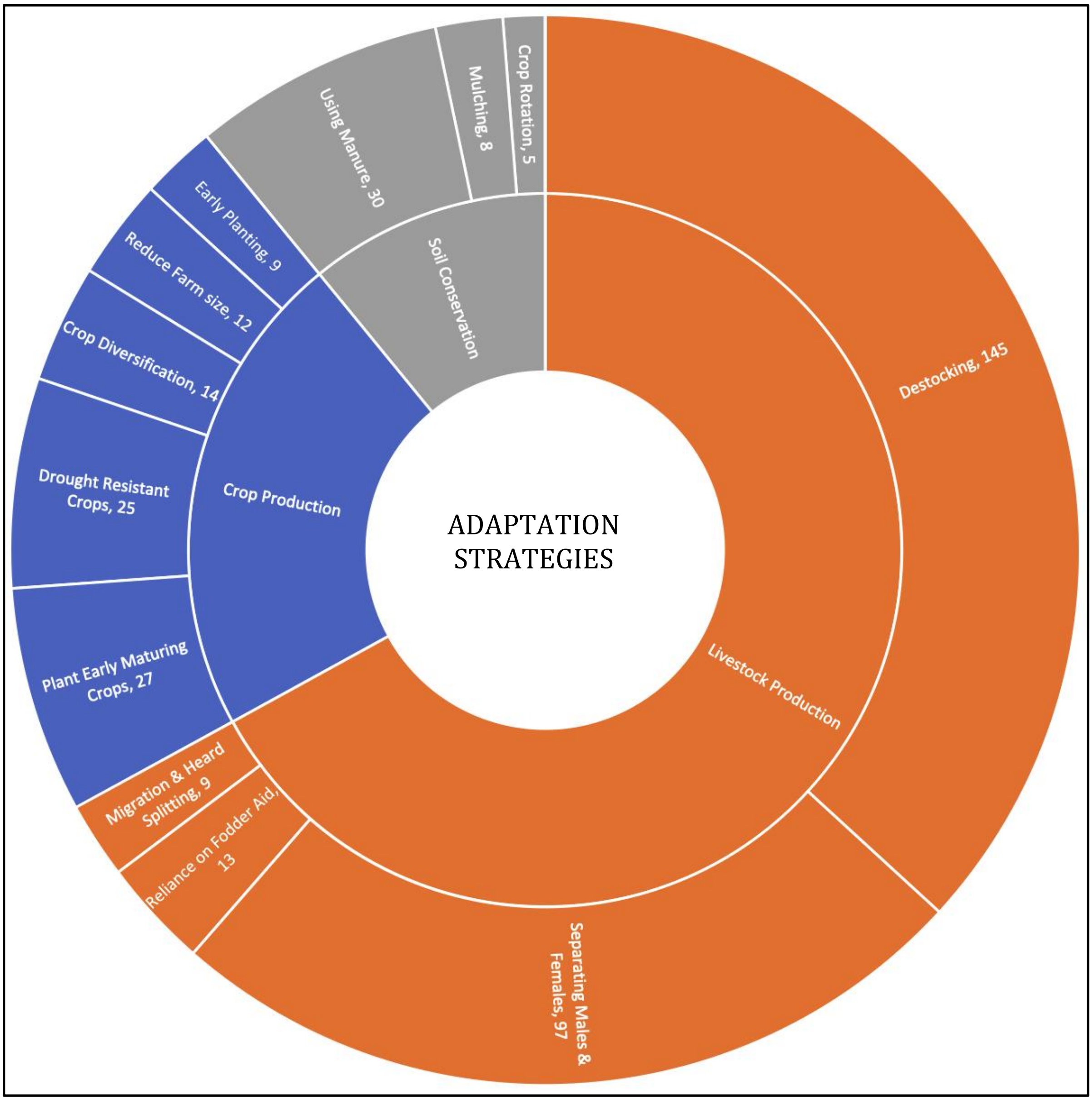

Figure 4.6 Adaptation strategies to climate change in Marsabit County

4.7.3.1 Livestock Adaptation Strategies among the Gabbra

The study established that the main livestock adaptation strategies to climate change impacts adopted by Gabbra pastoralists as follows (i) destocking (54.84 %),- This is mainly done at the onset of drought when the pastoralists would either sell some stock or redistribute among their kinsmen in areas further away (ii) separating males from females (36.77%) (see Plate 4.5). This is done in order to prevent breeding during drought periods and ensure that each animal had enough energy reserves to see them through the drought and related adversities. (iii) migration and herd splitting (3.54) and at times (iv) reliance on fodder aid (36.77%) (see Plate 4.6); as well as supplementing livestock fodder by utilizing tree leaves.

The Gabbra pastoralists additionally practice strict adherence to dry and wet grazing patterns (range management) and community governance. Such adaptations relate with those other pastoralists undertake elsewhere but with minor differences and which are largely conditioned by climate change factors at play e.g. drought, intensity and landscape conditions and resources available. Idrissou *et al*. (2020) found that cattle keepers in Benin's dry and sub-humid tropical zones cited mobility, crop husbandry integration, concentrate feed provision, herd size reduction, livestock diversification, and forage cropping as the most crucial adaptation strategies. Gabbra pastoralists reported being able to identify the shift in climate before these adaptation activities began. Livestock farmers are somewhat conscious of climate change, particularly the rise in temperature, according to Idrissou (2020).

According to cattle ranchers, mobility, integrating livestock with crop husbandry, offering concentrate feed, reducing herd size, animal variety, and forage cropping were the most crucial adaptation tactics. According to Salmora *et al*. (2020), farmers typically use three main strategies in response to droughts: managing the amount of grazing and feed that is available; selling livestock to reduce feed demand and to obtain income; and purchasing additional feed. These strategies are reactive, short-term coping mechanisms meant to address feed shortages.

4.7.3.2 Crops Adaptation Strategies among the Gabbra

Though the Gabbra community are pastoralists, a few households do practice limited farming, which is mainly done by women. In crop farming, adaptations concentrated mainly on crop and soil management. Adaptations targeting crops included adapt, common responses included planting different crops, changing crop varieties, changing planting dates, Early Planting, Plant Early Maturing Crops increasing irrigation, Crop Diversification, changing the amount of land under cultivation mainly by reducing crop farm size. With regard to soils, application of manure, mulching and crop rotation were the most common forms of adaptation. However, these agricultural adaptations targeting crops were done on a very limited scale since crop farming is still partial among the Gabbra.

4.7.3.3 Adaptation Strategies for Soil Improvement among the Gabbra

Strategies to improve soil fertility and moisture content undertaken by the Gabbra community are few as crop farming is only undertaken in very few households and at a very low scale. The use of manure was most common given that it is readily available due to large numbers of livestock kept at the Gabbra. Other soil management measures included crop rotation and mulching. The use of manure by - pastoralists has been made possible by its abundance in the area due to vast numbers of livestock. Application of manure in Gabbra farmer gardens', and which are mostly managed by women, and sedentary families contribute to increase in soil fertility, water retention and consequently on crop yields. Using manure in farming also helps store carbon in the soil and reduces its release into the atmosphere from livestock sheds, and in this way, communities contribute to reducing climate-changing emissions (Nyariki, D.M., Amwata, D.A.(2019)). Manure is also used on pastureland by pastoralists to allow for good pasture-stand establishment, promotes early growth, increases yield and quality and improves dry spell hardiness and persistence (WFP 2018).

4.7.4 Adaptation and Resilience

In addition to indigenous knowledge on weather prediction and indigenous adaptation strategies, the provision of a range of climate-related information, such as the severity of drought, variations in temperature and rainfall, will serve multiple purposes within the communities (Sraku-Lartey *et al* 2020). This is especially true when efforts are directed towards achieving sustainable resilience. Pastoralism experience, literacy level, household size, surrounding ecosystems and pastures, income, community groups cohesion, were factors that contributed enormously to pastoralists' adaptation to climate change. Understanding pastoralists' perception of and response to climatic change is necessary for sustainable adaptation strategies (Nkuba *et al.,* 2023). Perception strongly affects how farmers deal with climate-induced risks and opportunities, and the precise nature of their behavioural responses to this perception will shape adaptation options, the process involved and adaptation outcomes (Adger *et al*. 2009).

Local Gabbra communities were found not to have actively participated in decisions that ultimately influenced national policies on semi-arid and arid lands. Policies in place have largely been ascribed and with a prejudice against modern arid-lands agriculture and largely disapproving the views of the pastoralists, and whose occupation tends to be perceived as a declining way of life. Because of this mindset, the needs and goals for the development of Pastoralist-farming communities were found to be at the edge of increasing climate change. Pastoralists, pastoralists, and the communities they live in are acutely aware of the changing climate and its unpredictability, and they are quite gloomy about how this could affect their means of subsistence in the future. Despite different support and technological interventions being available. However, despite different types of support including technological interventions that may be available, constraints such as lack of finances, lack of information, shortage of expertise too has been noted (Mulinya 2017) as major constraints to coping with climate change effects in ASALs. In order to implement adaptation programs and create policies that drive the need for adaptation, it is imperative to secure the willing collaboration of the intended beneficiaries. Furthermore, it is essential to improve their comprehension of the dangers related to climate change so that they may set reasonable expectations and be better equipped to seize any opportunities that climate change may present as well as to prepare for any potential negative effects (Debela *et al.,* 2015).

4.8 Factors influencing pastoralists decision on adaptation to climate change

This study used a Multivariate Probit (MVP) model to analyze the factors affecting the decisions of Gabbra pastoralists to cultivate early maturing cultivars, adopt destocking as a climate mitigation strategy and use manure for soil amendment as a mitigation strategy (Table 4.10). The results show that gender of household head, age of household head, education of household head, monthly income (ln), household size, membership to social group, increasing temperature, unpredictable rainfall patterns, increased drought frequency, assistance from government, assistance from relatives, access to extension services, access to credit services, water availability, pasture availability, and own large herd of livestock significantly ($p<0.05$) affected the adoption of all the three adaptive practices in among the Gabbra pastoralists. These findings are very similar to the findings of Nhemachena and Hassan (2007) and Kibue *et al*. (2016) on how farmers in some African countries and China adapted to climate change.

In terms of specific adaptive strategies, households with heads who have formal education are more likely to cultivate early maturing cultivars varieties and also adopt destocking as a climate mitigation strategy to cope with climate change. The households with high monthly income are more likely to cultivate early maturing cultivars and also use manure for soil amendment as a mitigation strategy. The results show that pastoralists whose households are large in size are likely to use manure for soil amendment as a mitigation strategy. When a farmer is a member of a social group, the household is likely to use destocking of livestock and manure use as mitigation strategies. According to the results, a farmer who perceived increasing temperature is likely to adopt early maturing cultivars, destocking of livestock and use of manure for soil amendment as climate mitigation strategies. This is similar to the findings by Thoai *et al*. (2018) which found that access to credit and membership in local organizations significantly influence farmers' adaptive practices to climate change. Atube *et al.* (2021) used the binary logit regression model to analyse the determinants of smallholder farmers' adaptation strategies to the effects of climate change in northern Uganda. The authors found similar results that gender of household head, household size, marital status of household head, years of farming experience, size of land cultivated, time taken to market, farm income, access to agricultural extension services, and credit facilities significantly influenced the adoption of adaptation strategies.

The study results show that pastoralists who perceive unpredictable rainfall patterns are likely to cultivate early maturing cultivars and use manure for soil amendment as a mitigation strategy. However, perceived unpredictable rainfall patterns reduce the likelihood of destocking as a climate mitigation strategy. The pastoralists who receive assistance from the government are neither likely to adopt destocking nor use manure for soil amendment as a mitigation strategy. Households receiving assistance from relatives are less likely to either adopt destocking or use manure for soil amendment as a mitigation strategy. The farmers who have access to extension services were found to be likely to cultivate early maturing cultivars varieties and also use destocking of livestock as mitigation strategies. Access to credit services for pastoralists increases the likelihood of cultivating early maturing cultivars, adopting destocking and also using manure for soil amendment as a climate change mitigation strategy.

Water availability increases the likelihood of adopting early maturing cultivars, destocking of livestock and using manure for soil amendment in order to mitigate the impact of climate change among the Gabbra pastoralists in Marsabit County. The study results also show that farmers who have adequate pasture availability are likely to adopt destocking of their livestock as a climate change mitigation strategy. However, these households are not likely to either cultivate early maturing cultivars or use manure for soil amendment as a climate change mitigation strategy. The pastoralists who own large herds of livestock are likely to adopt destocking strategies to mitigate the impact of climate mitigation. However, the households are neither likely to cultivate early maturing cultivars as a mitigation strategy nor use manure for soil amendment as a mitigation strategy.

Table 4.10. Estimated result of the Multivariate Probit Model of determinants of pastoralists' adaptive practice to climate change

	Cultivating early maturing cultivars as a strategy			Destocking as a climate mitigation strategy			Using manure for soil amendment as a mitigation strategy		
Variable	Coef.	Std. Err.	z	Coef.	Std. Err.	z	Coef.	Std. Err.	z
Gender of household head	0.134	0.187	0.719	0.008	0.192	0.042	-0.456**	0.218	-2.095
Age of household head	-0.034*	0.016	-2.135	0.017***	0.006	2.727	-0.007	0.007	-0.979
Education of household head	0.864***	0.200	4.319	0.637***	0.229	2.784	-0.488*	0.262	-1.859
Monthly income (ln)	0.470***	0.094	4.984	0.074	0.091	0.806	0.123**	0.055	2.247
Household size	0.021	0.036	0.572	0.011	0.037	0.308	0.170***	0.042	4.058
Membership to social group	0.012	0.158	0.076	0.444***	0.165	2.694	0.379**	0.191	1.989
Increasing temperature	0.383**	0.167	2.292	0.435**	0.174	2.496	0.552***	0.206	2.686
Unpredictable rainfall patterns	0.481***	0.158	3.036	-0.349**	0.165	-2.119	0.722***	0.200	3.612
Increased drought frequency	0.087	0.176	0.496	-0.135	0.183	-0.739	0.986***	0.213	4.618
Assistance from government	-0.181	0.165	-1.096	-0.513***	0.169	-3.026	-0.457**	0.204	-2.237
Assistance from relatives	-0.055	0.166	-0.334	-0.398**	0.175	-2.268	-0.833***	0.190	-4.373
Access to extension services	0.494***	0.188	2.632	0.713***	0.193	3.685	0.160	0.225	0.710
Access to credit services	0.519**	0.259	2.005	0.584**	0.251	2.330	0.852***	0.301	2.835
Water availability	0.474**	0.208	2.284	0.584***	0.213	2.740	0.683***	0.241	2.836
Pasture availability	-0.425**	0.185	-2.302	0.399**	0.192	2.072	-0.544**	0.212	-2.562
Own large herd of livestock	-0.581**	0.280	-2.076	0.858***	0.280	3.061	-0.697**	0.355	-1.966
Constant	1.064	0.874	1.216	-0.892	0.862	-1.035	-0.825	0.997	-0.827

- Likelihood ratio test of rho21 = rho31 = rho32 = 0
- Chi2(3) = 8.24381 Prob > chi2 = 0.0412
- *** = significant at 1%; ** = significant at 5%; and *= significant at 10%

4.9 Livelihood Vulnerability Index - The Composite Index Approach

The livelihood vulnerability results were computed using the LVI composite index as well as the LVI-IPCC approaches (Tables 4.11 and Table 4.12). According to the analysis, North Horr is the most vulnerable sub-county to climate change (LVI = 0.337). Also, Moyale (LVI = 0.317), Marsabit North (LVI = 0.337) and Loiyangalani (LVI = 0.282) were also found to be highly vulnerable to climate change. Marsabit Central (LVI = 0.247), Sololo (LVI = 0.246) and Marsabit South (LVI = 0.168) are moderately vulnerable to climate change according to the analysis (Tables 4.13 and Table 4.14). An analysis of the major LVI components indicated that households in all sub counties were vulnerable to climate change in socio-demographic profile, livelihood strategies, social networks, food, water, and natural disasters and climate variability.

A spider diagram (Figure 4.7) was used to plot the LVI scores for North-Horr, Moyale, Marsabit North, Marsabit Central, Loiyangalani, Sololo sub counties. The diagram shows that Gabbra Community were more vulnerable to climate change in six components: socio-demographic profile, livelihood strategies, social networks, food, water, and natural disasters and climate variability. In Marsabit South, the Gabbra community were vulnerable to climate change in five components: livelihood strategies, social networks, food, water, and natural disasters and climate variability.

Table 4.11 LVI major Components and Sub-Components

Major component	Sub-components	Explanatory notes for sub-components	Units	Data source
Socio-demographic profile	Dependency ratio	Ratio of people aged 15 to 64 years old (inactive population) to people aged 15 to 64 years old (active population)	Ratio	Survey
	Proportion of male/female headed households	If a male household head is absent for more than six months, the female is considered the head of the household.	Percent	Survey
	Average age of male/female head of household	Household heads' average age	1/Years	Survey
	The proportion of households where the head of the household has not attended school	Percentage of households where the head of the household reports having attended 0 years of school	Percent	Survey
	The proportion of households with orphans	The proportion of households with at least one orphan under the age of 18 whose one or both parents have died.	Percent	Survey
Livelihood Strategies	The proportion of households in which no family member works in a different community.	Percentage of households where no family member works and earns a living outside of their community Question is modified to give a positive vulnerability score when a household doesn't have a member working outside the community	Percent	Survey
	Percentage of households whose sole source of income is pastoralism	Percentage of households reporting agriculture as their sole source of income	Percent	Survey
	Average agricultural livelihood diversification index	The inverse of (the number of agricultural livelihood activities reported by a household +1) The livelihood activities considered in this study included crop farming, animal rearing and collecting of natural resources for sale	1/#Livelihoods	Survey
Social Networks	Average receive: Give ratio	The ratio of (the number of types of help received by a household in the previous month +1) to (the number of	Ratio	Survey

Major component	Sub-components	Explanatory notes for sub-components	Units	Data source
		types of help given to someone else by a household in the previous month +1)		
	Average borrow: Lend money ratio	The ratio of a household borrowing money in the previous month to a household lending money in the previous month	Ratio	Survey
	Percentage of households that sought assistance from their local government in the previous 12 months	The percentage of households who reported seeking help from their local government. Question is modified to give a positive vulnerability score when a household seeks help as seeking help is seen as a sign of helplessness which signifies vulnerability	Percent	Survey
Health	Average time to health facility on foot	The average time it takes households to walk to the nearest health facility.	Minutes	Survey
	Percentage of households with a chronically ill family member	Percentage of households with at least one chronically ill member	Percent	Survey
	Percentage of households in which a family member missed work or school in the previous two weeks due to illness	The percentage of households where a member missed work or school in the previous two weeks due to illness.	Percent	Survey
	Average Malaria Exposure*Prevention Index	Months of malaria exposure*owning at least one bed net (with bed net = 0.5, without bed net = 1)	Months*Bed net Indicator	Survey
Food	Percentage of households relying solely on family farm for food	Percentage of households who solely rely on their family farm for food	Percent	Survey
	Average number of months households struggle to find food	Average number of months in a year households struggle with food shortage	Months	Survey
	Average Crop Diversity Index	The inverse of (a household's number of crops grown +1)	1/#Crops	Survey

Major component	Sub-components	Explanatory notes for sub-components	Units	Data source
	Percentage of households that do not save crops	Percentage of households that do not save crops from their harvest	Percent	Survey
	Percentage of households that do not save seeds	Percentage of households that do not save seeds for future seasons	Percent	Survey
Water	Percentage of households reporting a water conflict	Percentage of households reporting the occurrence of water conflicts in their community	Percent	Survey
	Percentage of households that use a natural water source	The proportion of households that get their water from natural sources such as rivers, streams, and traditional river wells.	Percent	Survey
	Average time to water source on foot	Average time households take to reach their primary water source on foot	Minutes	Survey
	Percentage of households without a reliable water supply	Percentage of households reporting that water is not available at their primary water source every day	Percent	Survey
	Inverse of the average amount of water stored per household.	The inverse of (the average number of litres of water stored by each household+1)	1/Litres	Survey
Natural Disasters and Climate Variability	Average number of floods, drought and windstorms in the past six years	Total number of droughts, floods and wind storms reported by households in the past six years	Count	Survey
	Percentage of households that did not receive a warning about impending natural disasters	Percentage of households who did not receive any prior warning about imminent natural disasters in the past six years	Percent	Survey
	Percentage of households affected by recent natural disasters in terms of injury or death	The proportion of households reporting a natural disaster-related death or injury in the previous six years.	Percent	Survey
	Mean standard deviation of monthly average of average maximum daily	The standard deviation of the average daily maximum temperature by month between 2015 and 2020	Celsius	Kenya Meteorological

Major component	Sub-components	Explanatory notes for sub-components	Units	Data source
	temperatures (last six years)			Department
	Mean standard deviation of monthly average of average minimum daily temperatures (last six years)	The standard deviation of the average daily minimum temperature by month between 2015 and 2020	Celsius	Kenya Meteorological Department
	Mean standard deviation of monthly average precipitation (last six years)	The standard deviation of the average monthly precipitation between 2015 and 2020	Millimeters	Kenya Meteorological Department

Source: Adapted from (Hahn *et al*., 2009).

Table 4.12. LVI-IPCC Vulnerability Contributory Factors

Vulnerability contributing factors	Main components
Sensitivity	Food, Health and Water
Exposure	Natural disasters and climate variability
Adaptive capacity	Socio-demographic profile, Social networks and Livelihood strategies

Table 4.13. Livelihood Vulnerability Results for Marsabit County

Sub-County	Major Component	Sub component	Units	Actual value	Max Value	Min value	Standardized value	Major component value
North Horr	Socio-Demographic Profile	Dependency ratio	Ratio	2.900	7.000	0.000	0.414	0.337
		Percentage of female-headed households	Percent	42.170	100.000	0.000	0.422	
		Average age of female head of household	1/Years	0.022	0.043	0.014	0.276	
		Percentage of households where head of household has not attended school	Percent	20.750	100.000	0.000	0.208	
		Percentage of households with orphans	Percent	36.460	100.000	0.000	0.365	
	Livelihood Strategies	Percentage of households without family member working in a different community	Percent	41.000	100.000	0.000	0.410	0.363
		Percentage of households dependent solely on agriculture as a source of income	Percent	52.000	100.000	0.000	0.520	
		Average agricultural livelihood diversification index	1/# Livelihoods	0.290	0.500	0.250	0.160	
	Social Networks	Average receive: Give ratio	Ratio	3.380	7.000	0.250	0.464	0.433
		Average borrow: Lend money ratio	Ratio	1.150	2.000	0.500	0.433	
		Percentage of households that have gone to their local government for assistance in the past 12 months	Percent	40.250	100.000	0.000	0.403	
	Health	Average time to health facility	Minutes	68.690	390.000	3.000	0.170	0.226
		Percentage of households with family member with chronic illness	Percent	36.410	100.000	0.000	0.364	
		Percentage of households where a family member had to miss work or school in the last two weeks due to illness	Percent	23.440	100.000	0.000	0.234	
		Average Malaria Exposure*Prevention Index	Months*Bednet Indicator	1.110	5.000	0.500	0.136	

Sub-County	Major Component	Sub component	Units	Actual value	Max Value	Min value	Standar dized value	Major component value
	Food	Percentage of households dependent solely on family farm for food	Percent	79.550	100.000	0.000	0.796	0.445
		Average number of months households struggle to find food	Months	2.860	12.000	0.000	0.238	
		Average Crop Diversity Index	1/# Crops	0.140	1.000	0.070	0.075	
		Percentage of households that do not save crops	Percent	43.750	100.000	0.000	0.438	
		Percentage of households that do not save seeds	Percent	68.000	100.000	0.000	0.680	
	Water	Percentage of households reporting water conflicts	Percent	67.000	100.000	0.000	0.670	0.578
		Percentage of households that utilize a natural water source	Percent	70.000	100.000	0.000	0.700	
		Average time to water source	Minutes	74.980	390.000	0.000	0.192	
		Percentage of households that do not have a consistent water supply	Percent	85.000	100.000	0.000	0.850	
		Inverse of the average number of litres of water stored per household	1/Litres	0.036	0.075	0.000	0.478	
	Natural Disasters and Climate Variability	Average number of floods, drought and windstorms in the past six years	Count	5.890	8.000	0.000	0.736	0.546
		Percentage of households that did not receive a warning about the pending natural disasters	Percent	47.250	100.000	0.000	0.473	
		Percentage of households with an injury or death as a result of recent natural disasters	Percent	5.750	100.000	0.000	0.058	
		Mean standard deviation of monthly average of average maximum daily temperatures (last six years)	Celsius	2.970	3.280	1.410	0.834	
		Mean standard deviation of monthly average of average minimum daily temperatures (last six years)	Celsius	1.240	1.570	0.770	0.588	

Sub-County	Major Component	Sub component	Units	Actual value	Max Value	Min value	Standardized value	Major component value
		Mean standard deviation of monthly average precipitation (last six years)	Millimeters	5.340	8.780	0.370	0.591	
Moyale	Socio-Demographic Profile	Dependency ratio	Ratio	2.900	7.000	0.000	0.414	0.317
		Percentage of female-headed households	Percent	32.170	100.000	0.000	0.322	
		Average age of female head of household	1/Years	0.022	0.043	0.014	0.276	
		Percentage of households where head of household has not attended school	Percent	20.750	100.000	0.000	0.208	
		Percentage of households with orphans	Percent	36.460	100.000	0.000	0.365	
	Livelihood Strategies	Percentage of households without family member working in a different community	Percent	41.000	100.000	0.000	0.410	0.363
		Percentage of households dependent solely on agriculture as a source of income	Percent	52.000	100.000	0.000	0.520	
		Average agricultural livelihood diversification index	1/# Livelihoods	0.290	0.500	0.250	0.160	
	Social Networks	Average receive: Give ratio	Ratio	3.380	7.000	0.250	0.464	0.433
		Average borrow: Lend money ratio	Ratio	1.150	2.000	0.500	0.433	
		Percentage of households that have gone to their local government for assistance in the past 12 months	Percent	40.250	100.000	0.000	0.403	
	Health	Average time to health facility	Minutes	68.690	390.000	3.000	0.170	0.226
		Percentage of households with family member with chronic illness	Percent	36.410	100.000	0.000	0.364	
		Percentage of households where a family member had to miss work or school in the last two weeks due to illness	Percent	23.440	100.000	0.000	0.234	

Sub-County	Major Component	Sub component	Units	Actual value	Max Value	Min value	Standardized value	Major component value
		Average Malaria Exposure*Prevention Index	Months*Bednet Indicator	1.110	5.000	0.500	0.136	
	Food	Percentage of households dependent solely on family farm for food	Percent	59.550	100.000	0.000	0.596	0.405
		Average number of months households struggle to find food	Months	2.860	12.000	0.000	0.238	
		Average Crop Diversity Index	1/# Crops	0.140	1.000	0.070	0.075	
		Percentage of households that do not save crops	Percent	43.750	100.000	0.000	0.438	
		Percentage of households that do not save seeds	Percent	68.000	100.000	0.000	0.680	
	Water	Percentage of households reporting water conflicts	Percent	67.000	100.000	0.000	0.670	0.573
		Percentage of households that utilize a natural water source	Percent	70.000	100.000	0.000	0.700	
		Average time to water source	Minutes	64.980	390.000	0.000	0.167	
		Percentage of households that do not have a consistent water supply	Percent	85.000	100.000	0.000	0.850	
		Inverse of the average number of litres of water stored per household	1/Litres	0.036	0.075	0.000	0.478	
	Natural Disasters and Climate Variability	Average number of floods, drought and windstorms in the past six years	Count	5.890	8.000	0.000	0.736	0.513
		Percentage of households that did not receive a warning about the pending natural disasters	Percent	27.250	100.000	0.000	0.273	
		Percentage of households with an injury or death as a result of recent natural disasters	Percent	5.750	100.000	0.000	0.058	
		Mean standard deviation of monthly average of average maximum daily temperatures (last six years)	Celsius	2.970	3.280	1.410	0.834	

Sub-County	Major Component	Sub component	Units	Actual value	Max Value	Min value	Standardized value	Major component value
		Mean standard deviation of monthly average of average minimum daily temperatures (last six years)	Celsius	1.240	1.570	0.770	0.588	
		Mean standard deviation of monthly average precipitation (last six years)	Millimeters	5.340	8.780	0.370	0.591	
Loiyangalani	Socio-Demographic Profile	Dependency ratio	Ratio	1.700	7.000	0.000	0.243	0.282
		Percentage of female-headed households	Percent	36.170	100.000	0.000	0.362	
		Average age of female head of household	1/Years	0.022	0.043	0.014	0.276	
		Percentage of households where head of household has not attended school	Percent	20.750	100.000	0.000	0.208	
		Percentage of households with orphans	Percent	32.160	100.000	0.000	0.322	
	Livelihood Strategies	Percentage of households without family member working in a different community	Percent	41.000	100.000	0.000	0.410	0.310
		Percentage of households dependent solely on agriculture as a source of income	Percent	52.000	100.000	0.000	0.520	
		Average agricultural livelihood diversification index	1/# Livelihoods	0.250	0.500	0.250	0.000	
	Social Networks	Average receive: Give ratio	Ratio	3.380	7.000	0.250	0.464	0.433
		Average borrow: Lend money ratio	Ratio	1.150	2.000	0.500	0.433	
		Percentage of households that have gone to their local government for assistance in the past 12 months	Percent	40.250	100.000	0.000	0.403	
	Health	Average time to health facility	Minutes	68.690	390.000	3.000	0.170	0.226
		Percentage of households with family member with chronic illness	Percent	36.410	100.000	0.000	0.364	
		Percentage of households where a family member had to miss work or	Percent	23.440	100.000	0.000	0.234	

Sub-County	Major Component	Sub component	Units	Actual value	Max Value	Min value	Standar dized value	Major component value
		school in the last two weeks due to illness						
		Average Malaria Exposure*Prevention Index	Months*Bednet Indicator	1.110	5.000	0.500	0.136	
	Food	Percentage of households dependent solely on family farm for food	Percent	51.550	100.000	0.000	0.516	0.389
		Average number of months households struggle to find food	Months	2.860	12.000	0.000	0.238	
		Average Crop Diversity Index	1/# Crops	0.140	1.000	0.070	0.075	
		Percentage of households that do not save crops	Percent	43.750	100.000	0.000	0.438	
		Percentage of households that do not save seeds	Percent	68.000	100.000	0.000	0.680	
	Water	Percentage of households reporting water conflicts	Percent	67.000	100.000	0.000	0.670	0.578
		Percentage of households that utilize a natural water source	Percent	70.000	100.000	0.000	0.700	
		Average time to water source	Minutes	74.980	390.000	0.000	0.192	
		Percentage of households that do not have a consistent water supply	Percent	85.000	100.000	0.000	0.850	
		Inverse of the average number of litres of water stored per household	1/Litres	0.036	0.075	0.000	0.478	
	Natural Disasters and Climate Variability	Average number of floods, drought and windstorms in the past six years	Count	4.690	8.000	0.000	0.586	0.490
		Percentage of households that did not receive a warning about the pending natural disasters	Percent	32.250	100.000	0.000	0.323	
		Percentage of households with an injury or death as a result of recent natural disasters	Percent	2.150	100.000	0.000	0.022	
		Mean standard deviation of monthly	Celsius	2.970	3.280	1.410	0.834	

Sub-County	Major Component	Sub component	Units	Actual value	Max Value	Min value	Standar dized value	Major component value
		average of average maximum daily temperatures (last six years)						
		Mean standard deviation of monthly average of average minimum daily temperatures (last six years)	Celsius	1.240	1.570	0.770	0.588	
		Mean standard deviation of monthly average precipitation (last six years)	Millimeters	5.340	8.780	0.370	0.591	
Marsabit South (Laisamis)	Socio-Demographic Profile	Dependency ratio	Ratio	1.190	7.000	0.000	0.170	0.168
		Percentage of female-headed households	Percent	22.170	100.000	0.000	0.222	
		Average age of female head of household	1/Years	0.022	0.043	0.014	0.276	
		Percentage of households where head of household has not attended school	Percent	10.750	100.000	0.000	0.108	
		Percentage of households with orphans	Percent	6.460	100.000	0.000	0.065	
	Livelihood Strategies	Percentage of households without family member working in a different community	Percent	41.000	100.000	0.000	0.410	0.363
		Percentage of households dependent solely on agriculture as a source of income	Percent	52.000	100.000	0.000	0.520	
		Average agricultural livelihood diversification index	1/# Livelihoods	0.290	0.500	0.250	0.160	
	Social Networks	Average receive: Give ratio	Ratio	3.380	7.000	0.250	0.464	0.370
		Average borrow: Lend money ratio	Ratio	1.150	2.000	0.500	0.433	
		Percentage of households that have gone to their local government for assistance in the past 12 months	Percent	21.250	100.000	0.000	0.213	
	Health	Average time to health facility	Minutes	68.690	390.000	3.000	0.170	0.226
		Percentage of households with family member with chronic illness	Percent	36.410	100.000	0.000	0.364	

Sub-County	Major Component	Sub component	Units	Actual value	Max Value	Min value	Standardized value	Major component value
		Percentage of households where a family member had to miss work or school in the last two weeks due to illness	Percent	23.440	100.000	0.000	0.234	
		Average Malaria Exposure*Prevention Index	Months*Bednet Indicator	1.110	5.000	0.500	0.136	
	Food	Percentage of households dependent solely on family farm for food	Percent	59.550	100.000	0.000	0.596	0.367
		Average number of months households struggle to find food	Months	2.860	12.000	0.000	0.238	
		Average Crop Diversity Index	1/# Crops	0.140	1.000	0.070	0.075	
		Percentage of households that do not save crops	Percent	24.750	100.000	0.000	0.248	
		Percentage of households that do not save seeds	Percent	68.000	100.000	0.000	0.680	
	Water	Percentage of households reporting water conflicts	Percent	67.000	100.000	0.000	0.670	0.567
		Percentage of households that utilize a natural water source	Percent	70.000	100.000	0.000	0.700	
		Average time to water source	Minutes	52.980	390.000	0.000	0.136	
		Percentage of households that do not have a consistent water supply	Percent	85.000	100.000	0.000	0.850	
		Inverse of the average number of litres of water stored per household	1/Litres	0.036	0.075	0.000	0.478	
	Natural Disasters and Climate Variability	Average number of floods, drought and windstorms in the past six years	Count	3.890	8.000	0.000	0.486	0.471
		Percentage of households that did not receive a warning about the pending natural disasters	Percent	27.250	100.000	0.000	0.273	

Sub-County	Major Component	Sub component	Units	Actual value	Max Value	Min value	Standardized value	Major component value
		Percentage of households with an injury or death as a result of recent natural disasters	Percent	5.750	100.000	0.000	0.058	
		Mean standard deviation of monthly average of average maximum daily temperatures (last six years)	Celsius	2.970	3.280	1.410	0.834	
		Mean standard deviation of monthly average of average minimum daily temperatures (last six years)	Celsius	1.240	1.570	0.770	0.588	
		Mean standard deviation of monthly average precipitation (last six years)	Millimeters	5.340	8.780	0.370	0.591	
Marsabit Central (Saku)	Socio-Demographic Profile	Dependency ratio	Ratio	1.490	7.000	0.000	0.213	0.247
		Percentage of female-headed households	Percent	22.170	100.000	0.000	0.222	
		Average age of female head of household	1/Years	0.022	0.043	0.014	0.276	
		Percentage of households where head of household has not attended school	Percent	20.750	100.000	0.000	0.208	
		Percentage of households with orphans	Percent	31.460	100.000	0.000	0.315	
	Livelihood Strategies	Percentage of households without family member working in a different community	Percent	41.000	100.000	0.000	0.410	0.363
		Percentage of households dependent solely on agriculture as a source of income	Percent	52.000	100.000	0.000	0.520	
		Average agricultural livelihood diversification index	1/# Livelihoods	0.290	0.500	0.250	0.160	
	Social	Average receive: Give ratio	Ratio	3.380	7.000	0.250	0.464	0.433

Sub-County	Major Component	Sub component	Units	Actual value	Max Value	Min value	Standar dized value	Major component value
	Networks	Average borrow: Lend money ratio	Ratio	1.150	2.000	0.500	0.433	
		Percentage of households that have gone to their local government for assistance in the past 12 months	Percent	40.250	100.000	0.000	0.403	
	Health	Average time to health facility	Minutes	58.690	390.000	3.000	0.144	0.164
		Percentage of households with family member with chronic illness	Percent	16.410	100.000	0.000	0.164	
		Percentage of households where a family member had to miss work or school in the last two weeks due to illness	Percent	21.440	100.000	0.000	0.214	
		Average Malaria Exposure*Prevention Index	Months*Bednet Indicator	1.110	5.000	0.500	0.136	
	Food	Percentage of households dependent solely on family farm for food	Percent	44.550	100.000	0.000	0.446	0.315
		Average number of months households struggle to find food	Months	2.860	12.000	0.000	0.238	
		Average Crop Diversity Index	1/# Crops	0.140	1.000	0.070	0.075	
		Percentage of households that do not save crops	Percent	13.750	100.000	0.000	0.138	
		Percentage of households that do not save seeds	Percent	68.000	100.000	0.000	0.680	
	Water	Percentage of households reporting water conflicts	Percent	67.000	100.000	0.000	0.670	0.545
		Percentage of households that utilize a natural water source	Percent	70.000	100.000	0.000	0.700	
		Average time to water source	Minutes	10.980	390.000	0.000	0.028	
		Percentage of households that do not have a consistent water supply	Percent	85.000	100.000	0.000	0.850	
		Inverse of the average number of litres of water stored per household	1/Litres	0.036	0.075	0.000	0.478	

Sub-County	Major Component	Sub component	Units	Actual value	Max Value	Min value	Standar dized value	Major component value
	Natural Disasters and Climate Variability	Average number of floods, drought and windstorms in the past six years	Count	2.190	8.000	0.000	0.274	0.420
		Percentage of households that did not receive a warning about the pending natural disasters	Percent	47.250	100.000	0.000	0.473	
		Percentage of households with an injury or death as a result of recent natural disasters	Percent	2.175	100.000	0.000	0.022	
		Mean standard deviation of monthly average of average maximum daily temperatures (last six years)	Celsius	2.970	3.280	1.410	0.834	
		Mean standard deviation of monthly average of average minimum daily temperatures (last six years)	Celsius	1.240	1.570	0.770	0.588	
		Mean standard deviation of monthly average precipitation (last six years)	Millimeters	3.140	8.780	0.370	0.329	
Marsabit North	Socio-Demographic Profile	Dependency ratio	Ratio	2.900	7.000	0.000	0.414	0.337
		Percentage of female-headed households	Percent	42.170	100.000	0.000	0.422	
		Average age of female head of household	1/Years	0.022	0.043	0.014	0.276	
		Percentage of households where head of household has not attended school	Percent	20.750	100.000	0.000	0.208	
		Percentage of households with orphans	Percent	36.460	100.000	0.000	0.365	
	Livelihood Strategies	Percentage of households without family member working in a different community	Percent	41.000	100.000	0.000	0.410	0.363
		Percentage of households dependent solely on agriculture as a source of income	Percent	52.000	100.000	0.000	0.520	
		Average agricultural livelihood	1/# Livelihoods	0.290	0.500	0.250	0.160	

Sub-County	Major Component	Sub component	Units	Actual value	Max Value	Min value	Standardized value	Major component value
		diversification index						
	Social Networks	Average receive: Give ratio	Ratio	3.380	7.000	0.250	0.464	0.433
		Average borrow: Lend money ratio	Ratio	1.150	2.000	0.500	0.433	
		Percentage of households that have gone to their local government for assistance in the past 12 months	Percent	40.250	100.000	0.000	0.403	
	Health	Average time to health facility	Minutes	68.690	390.000	3.000	0.170	0.226
		Percentage of households with family member with chronic illness	Percent	36.410	100.000	0.000	0.364	
		Percentage of households where a family member had to miss work or school in the last two weeks due to illness	Percent	23.440	100.000	0.000	0.234	
		Average Malaria Exposure*Prevention Index	Months*Bednet Indicator	1.110	5.000	0.500	0.136	
	Food	Percentage of households dependent solely on family farm for food	Percent	79.550	100.000	0.000	0.796	0.445
		Average number of months households struggle to find food	Months	2.860	12.000	0.000	0.238	
		Average Crop Diversity Index	1/# Crops	0.140	1.000	0.070	0.075	
		Percentage of households that do not save crops	Percent	43.750	100.000	0.000	0.438	
		Percentage of households that do not save seeds	Percent	68.000	100.000	0.000	0.680	
	Water	Percentage of households reporting water conflicts	Percent	67.000	100.000	0.000	0.670	0.578
		Percentage of households that utilize a natural water source	Percent	70.000	100.000	0.000	0.700	
		Average time to water source	Minutes	74.980	390.000	0.000	0.192	
		Percentage of households that do not have a consistent water supply	Percent	85.000	100.000	0.000	0.850	

Sub-County	Major Component	Sub component	Units	Actual value	Max Value	Min value	Standar dized value	Major component value
		Inverse of the average number of litres of water stored per household	1/Litres	0.036	0.075	0.000	0.478	
	Natural Disasters and Climate Variability	Average number of floods, drought and windstorms in the past six years	Count	5.890	8.000	0.000	0.736	0.546
		Percentage of households that did not receive a warning about the pending natural disasters	Percent	47.250	100.000	0.000	0.473	
		Percentage of households with an injury or death as a result of recent natural disasters	Percent	5.750	100.000	0.000	0.058	
		Mean standard deviation of monthly average of average maximum daily temperatures (last six years)	Celsius	2.970	3.280	1.410	0.834	
		Mean standard deviation of monthly average of average minimum daily temperatures (last six years)	Celsius	1.240	1.570	0.770	0.588	
		Mean standard deviation of monthly average precipitation (last six years)	Millimeters	5.340	8.780	0.370	0.591	
Sololo	Socio-Demographic Profile	Dependency ratio	Ratio	2.100	7.000	0.000	0.300	0.246
		Percentage of female-headed households	Percent	27.170	100.000	0.000	0.272	
		Average age of female head of household	1/Years	0.022	0.043	0.014	0.276	
		Percentage of households where head of household has not attended school	Percent	14.750	100.000	0.000	0.148	
		Percentage of households with orphans	Percent	23.460	100.000	0.000	0.235	
	Livelihood Strategies	Percentage of households without family member working in a different community	Percent	41.000	100.000	0.000	0.410	0.297
		Percentage of households dependent solely on agriculture as a source of income	Percent	32.000	100.000	0.000	0.320	

Sub-County	Major Component	Sub component	Units	Actual value	Max Value	Min value	Standardized value	Major component value
		Average agricultural livelihood diversification index	1/# Livelihoods	0.290	0.500	0.250	0.160	
	Social Networks	Average receive: Give ratio	Ratio	3.080	7.000	0.250	0.419	0.375
		Average borrow: Lend money ratio	Ratio	1.150	2.000	0.500	0.433	
		Percentage of households that have gone to their local government for assistance in the past 12 months	Percent	27.250	100.000	0.000	0.273	
	Health	Average time to health facility	Minutes	48.190	390.000	3.000	0.117	0.200
		Percentage of households with family member with chronic illness	Percent	31.410	100.000	0.000	0.314	
		Percentage of households where a family member had to miss work or school in the last two weeks due to illness	Percent	23.440	100.000	0.000	0.234	
		Average Malaria Exposure*Prevention Index	Months*Bednet Indicator	1.110	5.000	0.500	0.136	
	Food	Percentage of households dependent solely on family farm for food	Percent	42.550	100.000	0.000	0.426	0.371
		Average number of months households struggle to find food	Months	2.860	12.000	0.000	0.238	
		Average Crop Diversity Index	1/# Crops	0.140	1.000	0.070	0.075	
		Percentage of households that do not save crops	Percent	43.750	100.000	0.000	0.438	
		Percentage of households that do not save seeds	Percent	68.000	100.000	0.000	0.680	
	Water	Percentage of households reporting water conflicts	Percent	67.000	100.000	0.000	0.670	0.558
		Percentage of households that utilize a natural water source	Percent	70.000	100.000	0.000	0.700	
		Average time to water source	Minutes	34.980	390.000	0.000	0.090	
		Percentage of households that do not	Percent	85.000	100.000	0.000	0.850	

Sub-County	Major Component	Sub component	Units	Actual value	Max Value	Min value	Standardized value	Major component value
		have a consistent water supply						
		Inverse of the average number of litres of water stored per household	1/Litres	0.036	0.075	0.000	0.478	
	Natural Disasters and Climate Variability	Average number of floods, drought and windstorms in the past six years	Count	5.890	8.000	0.000	0.736	0.536
		Percentage of households that did not receive a warning about the pending natural disasters	Percent	41.250	100.000	0.000	0.413	
		Percentage of households with an injury or death as a result of recent natural disasters	Percent	5.750	100.000	0.000	0.058	
		Mean standard deviation of monthly average of average maximum daily temperatures (last six years)	Celsius	2.970	3.280	1.410	0.834	
		Mean standard deviation of monthly average of average minimum daily temperatures (last six years)	Celsius	1.240	1.570	0.770	0.588	
		Mean standard deviation of monthly average precipitation (last six years)	Millimeters	5.340	8.780	0.370	0.591	

Table 4.14. LVI for major Component and overall LVI Scores for Households in Marsabit County

Sub-County	Major Components							
	Socio-demographic	**Livelihood**	**Social**	**Health**	**Food**	**Water**	**Natural disasters and**	**Overall**

	profile	Strategies	Networks				climate variability	LVI
Moyale	0.317	0.363	0.433	0.226	0.405	0.573	0.513	0.317
Loiyangalani	0.282	0.310	0.433	0.226	0.389	0.578	0.490	0.282
Marsabit South	0.168	0.363	0.370	0.226	0.367	0.567	0.471	0.168
Marsabit Central	0.247	0.363	0.433	0.164	0.315	0.545	0.420	0.247
Marsabit North	0.337	0.363	0.433	0.226	0.445	0.578	0.546	0.337
Sololo	0.246	0.297	0.375	0.200	0.371	0.558	0.536	0.246
North Horr	0.337	0.363	0.433	0.226	0.445	0.578	0.546	0.337

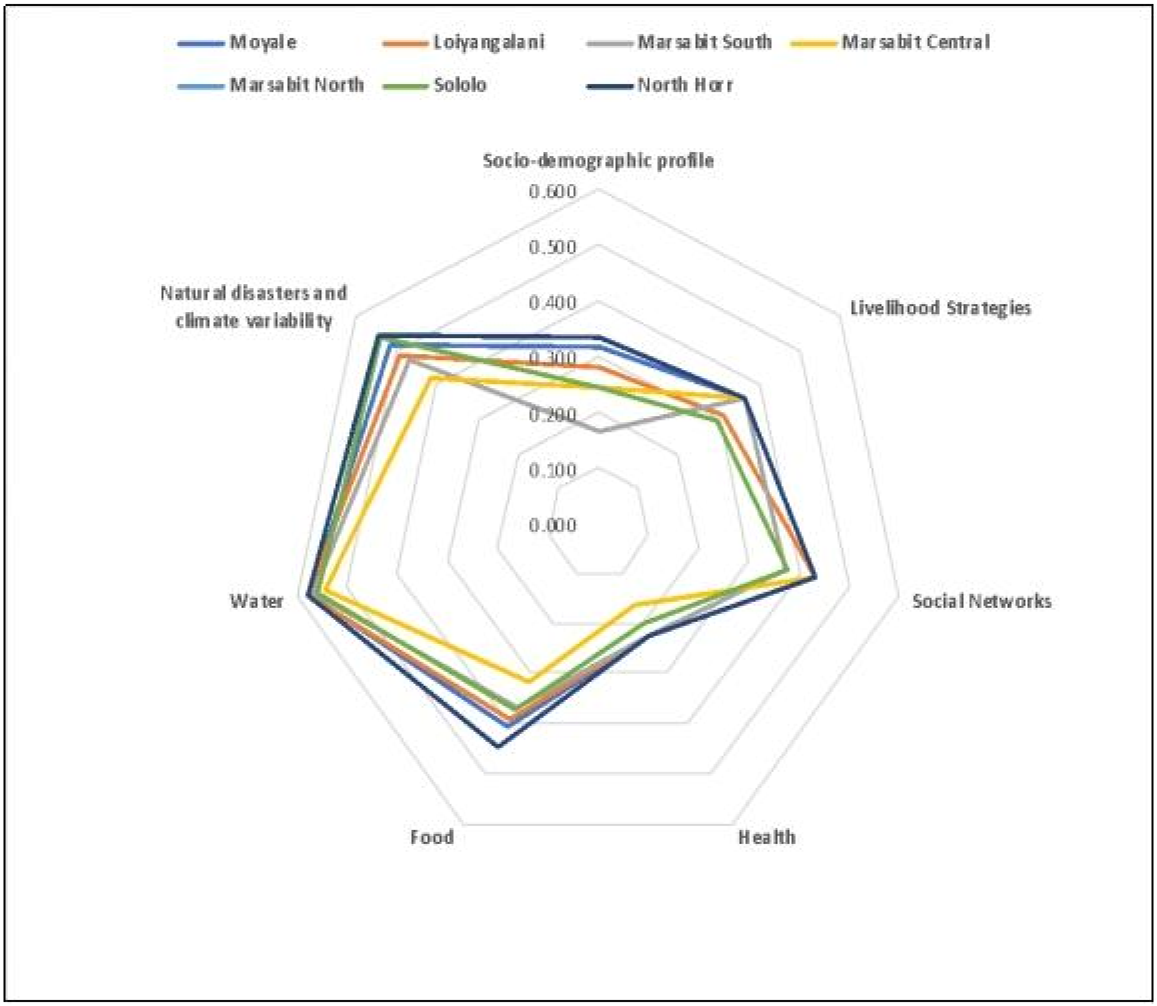

Figure 4.7: Vulnerability spider diagram of major components of the livelihood vulnerability index for Gabbra Community in Marsabit County

The results of this study reveal that vulnerability is conditioned by environmental circumstances, geography, social structures, time, social position, availability of livelihood opportunities and also availability of resources. Similar results have been obtained by other studies (Muia *et al*., 2024). The vulnerability of Gabbra community to climate change can be partly attributed to illiteracy, insufficient resources, and limited access to information (Abbasi *et al*., 2019). -pastoralists diversify their income through growing of crops besides keeping livestock. Also, the Gabbra households have been sending their husbands and sons outside the community to work and send remittances home as a coping strategy. Collection of natural resources for sale in the local markets has been used as an alternative source of income among the pastoral community.

Household characteristics contribute to the vulnerability of the Gabbra community to climate change in all the studied sub-counties. For example, the distance to water sources has increased following the increased frequency of drought. This may be the reason for high vulnerability scores for water major components in all the sub-counties. Related studies have also shown vulnerability in terms of livelihood strategies and water main components due to difficulty in procuring the resource (Alhassan *et al*., 2019).

In all the sub-counties of Marsabit County, -pastoralists are dependent on natural resources for maintenance of their livelihood. This implies that the livelihood of households are highly vulnerable to climate change. Lack of preparation for potential climate shocks may be responsible for high vulnerability scores in the food sector. These findings relate to the study by Abbasi *et al*., (2019), which attributed food insecurity to climate drought. The county of Marsabit has been impacted by a high number of natural disasters over the last six years. This has been exacerbated by a variability in monthly average minimum and maximum daily term.

The vulnerability of Gabbra households in Loiyangalani, Marsabit Central, Marsabit North, Marsabit South, Moyale, North Horr and Sololo is not statistically different (Table 4.15). This may be attributed to their similar ways of life and the relatively similar climate shocks in the spatial area. An analysis of the mean LVI obtained from all the seven sub-counties of Marsabit County shows that all the Gabbra households are significantly ($p<0.01$) vulnerable to climate change (Table 4.16). Filho *et al*. (2020) observes that the long-term sustainability of the livelihoods of pastoral communities is currently endangered by climate change and the risks and hazards it brings about, which may worsen poverty among this social group. The vulnerability to climate change for the community is largely contributed by all the major components of LVI: Socio-demographic profile, Livelihood Strategies, Social Networks, Health, Food, Water and Natural disasters and climate variability.

Table 4.15 Results of Analysis of Variance of the Difference in mean LVI

Variable	Obs.	Mean	Std. Dev.	Std. Err.	F-value	Pr(>F)
Loiyangalani	40	0.387	0.124	0.047	0.308	0.929
Marsabit	60					
Central		0.355	0.127	0.048		
Marsabit North	81	0.418	0.122	0.046		
Marsabit South	39	0.362	0.135	0.051		
Moyale	50	0.404	0.117	0.044		
North Horr	91	0.418	0.122	0.046		
Sololo	37	0.357	0.125	0.043		

Table 4.16 One-Sample t-Test for mean LVI

Mean LVI	t-statistic	df	p-value	95% CI
0.276	*11.92*	*6*	*2.111e-05*	*0.219 - 0.333*

4.10 The LVI-IPCC Method

A summary of results of the study obtained using the LVI-IPCC model are provided in Table 4.16 below (Table 17). According to the results, all the seven sub counties considered in the study indicated that Gabbra community was vulnerable to climate change: Sololo (IPCC-LVI=0.094), Marsabit South (IPCC-LVI=0.078), Marsabit North (IPCC-LVI=0.076), North Horr (IPCC-LVI=0.076), Loiyangalani (IPCC-LVI=0.065), Moyale (IPCC-LVI=0.063) and, Marsabit Central (IPCC-LVI=0.032). All the LVI-IPCC vulnerability contributory factors, adaptive capacity, sensitivity and exposure, revealed distinct disparities over all the sub-counties.

A vulnerability triangle was plotted using the LVI-IPCC scores (Figure 4.8). According to the figure, Gabbra communities are vulnerable in all the three indicators of livelihood vulnerability. The sub-county which had the highest adaptive capacity (0.370) were Marsabit North and Sololo. Marsabit North and Sololo were found to have highest sensitivity (0.430) to climate change. The sub-counties which had highest exposure (0.546) were Marsabit North and Sololo.

Table 4.17. LVI-IPCC scores for households in Marsabit County

Sub-County	Obs.	Adaptive capacity	Sensitivity	Exposure	LVI-IPCC
Moyale	40	0.361	0.414	0.513	0.063
Loiyangalani	60	0.331	0.410	0.490	0.065
Marsabit South	81	0.276	0.398	0.471	0.078
Marsabit Central	39	0.329	0.354	0.420	0.032
Marsabit North	50	0.370	0.430	0.546	0.076
North Horr	91	0.295	0.389	0.536	0.094
Sololo	37	0.370	0.430	0.546	0.076

The LVI-IPCC findings show that the Gabbra community is vulnerable to climate change. This is attributed to demographic imbalance, low diversification of livelihood strategies and poor storage of food. Since the adaptation strategies by -pastoralists are low, sensitivity to climate change has increased. Poor adaptation to climate change may also be linked to low household income. The study by Muia *et al*., (2024) linked high vulnerability to adaptive capacity for households, since people with lower income are usually poor and thus lack assets to liquidate. In addition, lack of secure land tenure to support land use investments can affect adaptation to climate change (Alhassan *et al*., 2019; Basiru *et al*., 2022).

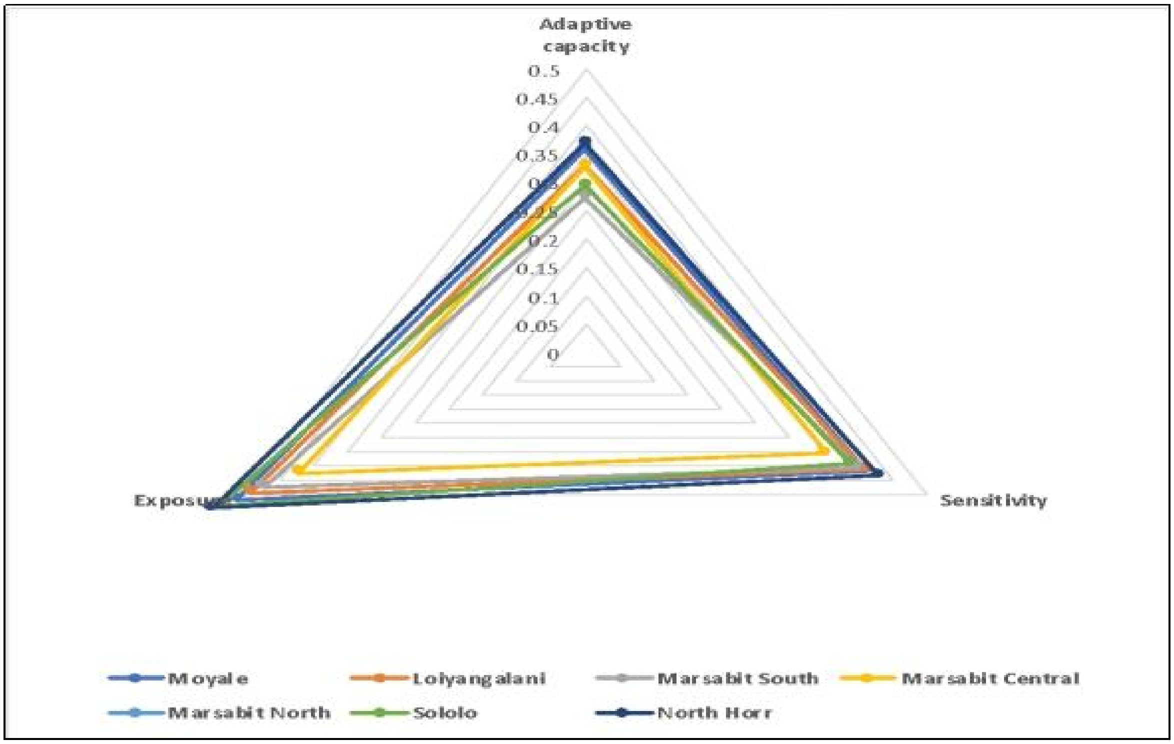

Figure 4.8. Vulnerability triangle diagram of the contributing factors of the livelihood vulnerability index-IPCC for Gabbra Community in Marsabit County

Statistical analysis was conducted to determine whether there was any statistically significant difference between the mean LVI-IPCC of Gabbra households living in different parts of Marsabit County (Table 4.17). The findings indicate that there was no significant difference between values of the LVI-IPCC of the households living in Loiyangalani, Marsabit Central, Marsabit North, Marsabit South, Moyale, North Horr and Sololo. This may be explained by the fact that climate shocks across the region are similar. Also, the lifestyle of Gabbra households across the study area is similar. The LVI-IPCC scale ranges from -1 (least vulnerable) to +1 (most vulnerable) according to Hahn *et al*., (2009). Using a t-Test, the Gabbra households were found to be significantly ($p<0.01$) vulnerable to climate change (Table 4.18). This may be explained by high exposure to climate shocks and low adaptive capacity of the Gabbra households to climate change.

Table 4.18 Results of Analysis of Variance of the difference in mean LVI-IPCC

Variable	Obs.	Mean	Std. Dev.	Std. Err.	F-value	p - value
Loiyangalani	40	0.410	0.080	0.046	0.376	0.882
Marsabit Central	60	0.368	0.047	0.027		
Marsabit North	81	0.449	0.089	0.052		
Marsabit South	39	0.382	0.099	0.057		
Moyale	50	0.429	0.077	0.045		
North Horr	91	0.449	0.090	0.052		
Sololo	37	0.407	0.121	0.070		

Table 4.19 One-Sample t-Test for mean LVI-IPCC

Mean LVI-IPCC	t-statistic	df	p-value	95% CI
0.276	*146.9*	*6*	*6.713e-12*	*0.0513 - 0.087*

CHAPTER FIVE

FINDINGS OF THE STUDY, CONCLUSION AND RECOMMENDATIONS

5.1 Findings of the Study

The trend analysis of time series data from 1990 to 2020 for precipitation and temperature in Marsabit county was based on Mann–Kendall test and Theil-Sen's slope estimator. All the sub-counties where Gabbra pastoralists live were selected as target population for sampling. These include North-Horr, Moyale, Marsabit North, Marsabit Central, Marsabit South, Loiyangalani, and Sololo sub-counties. The data analysis shows that there is no statistically significant ($p \leq 0.05$) positive trend of precipitation in Marsabit County. The decomposition additive time series was also used to confirm results. The monthly data shows maximum temperature had a significantly increasing trend in July, September and December from 1990 to 2022. Also, the monthly minimum temperature shows a significant ($p \leq 0.05$) trend in the months of August, September and October According to the time series data from 1990 to 2022.

The study assessed Gabbra pastoralists' perception of climate change taking place in their region. In all sub-locations surveyed, there was widespread consensus among Gabbra pastoralists on the occurrence of climate change and which they perceived through disruptions of their normal socio-economic activities and lifestyles. Most of the parameters on climate change detection such as delayed rainfall, droughts, flood disasters among others with most perception parameters used in perception being similar, across the sub-locations.

Rainfall and temperature changes were of great concern to the Gabbra pastoralists as they directly affected availability of water and pasture conditions, which support livestock and which are central to their livelihoods. The Gabbra pastoralists perceived extreme events or indicators associated directly with livelihood activities such as crop failures, dried up water sources, dust bowls during droughts among others as most suppressing. In some areas, different respondents of Gabbra pastoralists would observe climate change through different parameters such as increasing temperatures in dry season by some respondents;

and prolonged drought by others yet all indicating climate change but seen through differing perceptions.

This study also evaluated the impacts of climate change on Gabbra pastoralists. Impact detection parameters included delayed onset of rains, delayed ending of rains, decreased rainfall amounts, very short rain, and more dry spells among others. Climate impacts were largely attributed to rainfall and temperature variations as they were key determinants of impacts either of droughts and floods among others. While the Gabbra pastoralists had ways of adapting to climate change impacts especially focused on livestock, crops and soils management. Adapting to climate change was highly influenced by the unpredictable nature of occurrence of the various elements of climate change and corresponding severity levels.

Results showed overwhelming negative impacts on these elements especially rainfall anomalies with most reflecting decreases which result in droughts, loss of pastures, water scarcity and subsequently livestock deterioration and deaths. Respondents also reported that occasionally, very heavy rainfall would be experienced and for very short durations of 1-3 weeks during which time severe floods would occur leading to the Gabbra pastoralists incurring huge livestock losses.

The study analyzed temperature during the long-rain (March-April-May) and short-rain (October-November-December) seasons using the data from 1990 to 2022. The findings of this study show that minimum temperature had a significantly ($p \leq 0.05$) positive trend during the long rains. The annual data from Marsabit County was also analyzed for trends from 1990 to 2022. The findings show significantly ($p \leq 0.05$) positive trends of maximum and maximum temperature in the county. According to the results, minimum temperature trends were statistically ($p \leq 0.05$) significant in Moyale, Loiyangalani and Sololo sub counties. Further analysis of data from sub-counties indicated a positive and significant ($p \leq 0.05$) precipitation trend in Loiyangalani. Significantly ($p \leq 0.05$) positive trends were observed in the data from Moyale, Marsabit South, Marsabit Central, Sololo, and North Horr sub counties.

This study used composite index and LVI-IPCC approaches in assessing vulnerability of livelihoods to climate change, which involved identification of the sectors and contributing factors that determine the potential risks. In order to ensure additional information about the vulnerability of Gabbra community to climate change was obtained, different sub-counties were compared using a vulnerability spider diagram. The Gabbra households in all the seven sub-counties of Marsabit County are vulnerable to climate change. Generally, the major contributing factors to the composite vulnerability index in the study area are: food, water, natural disasters and climate change. Most Gabbra households struggle to find food thus increasing the contribution of food components to overall household vulnerability. The low average crop diversity index has also affected the component. Water component has also been affected by an increased percentage of households reporting water conflicts, long distance, and thus time, to water sources for the Gabbra households. Another important sub-component responsible for the water component in Marsabit is the high number of households without consistent water supply. The contributing sub-components to natural disasters and climate vulnerability are: high number of floods and drought in the last six years; low number of households receiving warning about natural disasters, and increased number of households with injury or death as a result of recent natural disasters.

5.2 Conclusion

The study examines monthly, seasonal, and annual trends of precipitation, maximum temperature and minimum temperature in the County of Marsabit from 1990 to 2022. It also examined the Gabbra pastoralists' perception on climate change and variability, impacts and adaptations. The Gabbra households' vulnerability to climate change was also assed.

The study makes the following conclusions:

1. There has been a decline in precipitation and increase in both maximum temperature and minimum temperature in the county. However, there are variations across the sub-counties. These trends demonstrate that while temperature is increasing with time, the rainfall does not follow the same trend.

2. The increasing temperature and declining precipitation in Marsabit County might be indicative of broader climate change trends affecting the North Eastern region of Kenya. These changes could have significant impacts on local ecosystems, agriculture, and water availability, potentially leading to challenges for Gabbra communities who are reliant on pastoralism for their livelihoods.

3. The pastoral areas of Gabbra community in Marsabit County have been experiencing a statistically significant increase in annual temperature trends from 1990 to 2022; Moyale and Sololo have been experiencing a downward but non-significant precipitation trend whereas in Marsabit South, Marsabit Central and North Horr the rainfall has been having an upward but non-significant trend. However, the precipitation in Loiyangalani has been having a significantly increasing trend; The annual precipitation trends from 1990 to 2022 have been declining albeit the change is not statistically significant; The annual maximum temperature in all the Marsabit sub-counties inhabited by the Gabbra community have been significantly increasing except for Loiyangalani and Marsabit Central; while Moyale, Loiyangalani and Sololo have been experiencing a significant increase in trend for annual minimum temperature. However, the upward trend for minimum temperature in Marsabit South, Marsabit Central, Marsabit North and North Horr is not statistically significant.

4. The Gabbra pastoralists have been perceiving climate through disruptions of their normal socio-economic activities and lifestyles. Most of the parameters on climate change detection from the pastoralists were such as delayed rainfall,

prolonged droughts, extensive flood disasters among others. Most perception parameters used in perception were largely similar, across the locations.

5. Climate change impacts among the Gabbra pastoralists are largely occasioned by rainfall scarcity which lead to prolonged drought and pasture losses or by very short and intense rainfall leading to flooding with both leading to enormous livestock losses and consequential livelihoods deterioration.

6. Among the Gabbra pastoralists adapting to climate change is a major challenge largely due the unpredictable nature of occurrence of its various elements and severity levels.

7. How Gabbra pastoralists understand or perceive climate change, and the phenomenon, the magnitude, of the resultant impact are crucial in determination of adaptation strategies undertaken and in development of policies.
8. While adaptations have been through varied interventions, indigenous knowledge among Gabbra pastoralists was found to be critical in predicting and interpreting climate variability and change, as well as in adaptation actions.

9. The choice of adaptation strategies to mitigate against the impacts of climate change in Marsabit County is significantly influenced by gender of household head, age of household head, education of household head, monthly income, household size, membership to social group, increasing temperature, unpredictable rainfall patterns, increased drought frequency , assistance from government, assistance from relatives, access to extension services, access to credit services, water availability, pasture availability, and own large herd of livestock.

10. Livelihood vulnerability indices: the LVI and the LVI-IPCC proved robust in analysis of vulnerability diversity in Marsabit County. The study concluded that livelihood vulnerability is intertwined with community inequality patterns and location differentiation.

11. The on-going trends of increased sedentary lifestyles and pasture demarcations appeared to increase Gabbra pastoralists' vulnerability.

12. Socio-demographic profile, livelihood strategies, social network, health, food, water, natural disasters and climate variability were found to have overlapping effects. These factors, in turn, increase the exposure to and sensitivity to climate change, while limiting their adaptive capacity.

5.3 Recommendations

Based on this study, the following policy recommendations have been made:

1. The reduction in monthly, seasonal and annual precipitation experienced in Marsabit County should prompt the livestock sector to initiate climate resilience programs to ensure sustainable livelihoods.
2. This study recommends exploitation of groundwater resources to supplement the limited surface water resources in the face of declining precipitation during the short-rain and long-rain seasons in Marsabit County.
3. There is a need for long-term adaptation strategies, such as the construction of water harvesting dams, to mitigate impacts such as those on livelihoods.
4. The county government of Marsabit should facilitate easy access to extension services and credit services to Gabbra pastoralists in order to promote better adaptation strategies to climate change such as cultivation of cultivating early maturing cultivars as a mitigation strategy; destocking as a climate mitigation strategy; and using manure for soil amendment as a mitigation strategy.
5. The declining precipitation coupled with increasing temperature might affect pasture in the grazing lands of Gabbra communities. There is a need for reseeding the Gabbra rangelands to guarantee adequate grass for livestock.
6. There is a need for the County Government of Marsabit and the National Government, through the Ministry of Environment and Forest, to design climate-related interventions that boost resilience of the Gabbra Community through diversification of

livelihoods thus enhancing the adaptive capacity of pastoral households. It is also important for the respective governments to promote climate change mitigation programmes in the county to address the related climate shock. Policy instruments should be developed to address the primary drivers of livelihood vulnerability of Gabbra community to climate change.

5.4 Recommendations for Further Research

Based on the findings and gaps identified in this study, the following recommendations are proposed for further research to deepen the understanding of climate change impacts, vulnerability, and adaptation strategies among pastoral communities, particularly the Gabbra pastoralists in Marsabit County, Kenya:

1. Long-Term Climate Data Analysis:
    - Recommendation: Future studies should focus on extending the temporal scope of climate data analysis beyond 2022 to capture more recent trends and variability in temperature and precipitation. This will provide a more comprehensive understanding of long-term climate change impacts in Marsabit County.
    - Rationale: The current study analyzed data up to 2022, but climate patterns are continuously evolving. Extending the analysis will help in identifying emerging trends and their implications for pastoral livelihoods.

2. Gender-Specific Vulnerability and Adaptation:
    - Recommendation: Conduct gender-disaggregated research to explore how climate change impacts and adaptation strategies differ between men and women within the Gabbra community.
    - Rationale: Women often bear a disproportionate burden of climate change impacts due to their roles in household management and resource collection. Understanding gender-specific vulnerabilities can inform more inclusive and effective adaptation strategies.

3. Indigenous Knowledge Integration:

- Recommendation: Investigate the integration of indigenous knowledge with modern climate-smart technologies to enhance the resilience of pastoral communities.
- Rationale: Indigenous knowledge has been a cornerstone of pastoral adaptation strategies. Research on how to effectively combine traditional practices with modern technologies can lead to more sustainable and culturally appropriate solutions.

4. Economic Diversification Strategies:
   - Recommendation: Explore alternative livelihood options and economic diversification strategies for pastoral communities to reduce their dependence on livestock and natural resources.
   - Rationale: Diversifying income sources can enhance the resilience of pastoral households to climate shocks. Research on viable alternative livelihoods, such as agro-pastoralism, small-scale businesses, and value-added livestock products, is essential.

5. Impact of Land Tenure Changes:
   - Recommendation: Study the impact of land tenure changes, including privatization and sedentarization, on the vulnerability and adaptive capacity of pastoral communities.
   - Rationale: Changes in land tenure systems can significantly affect access to grazing lands and water resources, thereby influencing the resilience of pastoral livelihoods. Understanding these dynamics is crucial for informed policy-making.

6. Health and Nutrition Impacts:
   - Recommendation: Investigate the health and nutrition impacts of climate change on pastoral communities, particularly in terms of food security and access to healthcare.
   - Rationale: Climate change can exacerbate food insecurity and health challenges in pastoral areas. Research in this area can inform interventions aimed at improving health outcomes and nutritional status.

7. Community-Based Adaptation Initiatives:

- Recommendation: Evaluate the effectiveness of community-based adaptation initiatives and their scalability across different pastoral regions.
- Rationale: Community-driven approaches are often more sustainable and culturally appropriate. Assessing their success and scalability can provide valuable lessons for broader application.

8. Policy and Institutional Support:
   - Recommendation: Conduct research on the role of policy and institutional support in enhancing the adaptive capacity of pastoral communities.
   - Rationale: Effective policies and institutional frameworks are critical for supporting climate adaptation efforts. Research in this area can identify gaps and opportunities for strengthening governance and support systems.

9. Climate Change Education and Awareness:
   - Recommendation: Explore the role of education and awareness programs in enhancing the adaptive capacity of pastoral communities.
   - Rationale: Increasing awareness and understanding of climate change impacts and adaptation strategies can empower communities to take proactive measures. Research on effective education and awareness initiatives is essential.

10. Cross-Regional Comparative Studies:
    - Recommendation: Undertake cross-regional comparative studies to understand the differential impacts of climate change and adaptation strategies across various pastoral communities in Kenya and beyond.
    - Rationale: Comparative studies can provide insights into best practices and lessons learned from different regions, contributing to a more holistic understanding of climate change adaptation in pastoral contexts.

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APPENDIX 1: QUESTIONNAIRE

PREAMBLE

Dear Respondent,

Mamo Boru Mamo is my name. At Kenyatta University, I am pursuing a PhD in Climate Change and Sustainable Development. I'm collecting data for a study on the impact of climate change and variability on Gabbra pastoralists' perceptions and adaptation strategies in Kenya's northern rangelands. This study and survey are solely for academic purposes. Your information will be kept strictly confidential and will not be used to identify you. As a result, your identity will be concealed. Your participation in this interview is entirely voluntary, and you will receive no immediate benefits. Your assistance in providing true and correct answers will be greatly appreciated.

Yours Sincerely,

Mamo Boru Mamo

GENERAL INFORMATION

Serial number of the questionnaire: ....

Date: ....

Village: ....

Ward: ....

Sub-country: ....

Name of Respondent: ....

Mobile No.: ....

Name of the Enumerator: ....

Mobile No.: ....

SECTION A: GENERAL INFORMATION AND VULNERABILITY TO CLIMATE CHANGE

Part A: Socio-Demographic Profile

1. Gender of household head

Male ☐

Female ☐

2. Age of household head (years) ___________

3. Household head years of education (total number of years spent in school) __________

4. Household head highest level of education

a) No education ☐

b) Pre-primary level ☐
c) Primary level ☐☐
d) Secondary level
e) Vocational or college ☐
f) Degree qualification ☐
g) Post graduate qualification ☐

5. Household head monthly income (Kshs) _________________

6. Household size

(a) How many members are there in your household (both children and adults)?_________________

(b) Could you please list the ages and sexes of all the members of your household

Name	**Relation**	**Age (Years)**	**Sex (M/F)**
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			

17			
18			
19			
20			

7. Are there children (below 18 years of age) living in your family because they are orphans? (one or both of their parents died)

Yes ☐

No☐

If Yes, how many? ________________

Part B: Livelihoods

8. What is the estimated value of your:

a) Farm equipment Kshs. _________________

b) Furniture Kshs. ______________________

9. (a) Is there a member or members of your family who are currently working outside this village or community?

Yes ☐

No☐

(b) If yes in (a) above, how many? ______________________

10. (a) Do you rear animals?

Yes ☐

No☐

(b) If Yes in (a) above, please indicate the number of livestock you own

Type of livestock	**Number owned**
Oxen (mature bull)	
Young bulls	
Cow (mature female – given birth)	
Heifer (young female-not given birth)	

Calves	
Camel	
Sheep	
Goats	
Chicken	
Ducks	
Pigs	
Rabbits	
Donkey	
Other ____________	

11. (a) Do you or someone else in your family collect natural resources like water, charcoal, firewood, timber, wild fruits, medicinal plants, stones, raisins and others for sale?

Yes ☐

No☐

(b) If Yes in (a) above, please state in your opinion how the amount of resources your family has been collecting has changed since the time you began collecting up to now

- Increased ☐
- Remained the same ☐
- Decreased☐
- Don't know☐

Part C: Health

12. What are the most frequent health problems in your village?

Malaria	
Typhoid	
Cholera	
HIV	
TB	
Others (please specify)	

13. Which months of the year is malaria particularly bad?

January	
February	
March	
April	
May	
June	
July	
August	
September	
October	
November	
December	

14. How many mosquito nets do you have?

None ☐

1☐

2 ☐

3☐

4 ☐

5☐

Other _____________

15. Do you have a latrine or toilet in your homestead?

Yes ☐

No☐

16. How long does it take you to get to a health facility?

______________ Hours______________ Minutes

17. (a) Is there anybody in your family who is chronically ill?

Yes ☐

No☐

(b) If Yes in the above, what are they suffering from?

HIV	
Diabetes	
High blood pressure	
Arthritis	
Cancer	
Asthma	
TB	
Other (please specify)	

18. (a) Has anyone in your family been so sick in the past two weeks that they had to miss work or school?

Yes ☐

No☐

(b) If Yes in the above, how many days of work or school did they miss? ____________________

Part D: Food

---

19. Where does your household get **MOST** of its food from? (*tick one-the main one*)

- Grown by family (farm)☐
- Bought☐
- Relief food ☐
- Collected from forest/wild☐
- Others (please specify)

____

20. (a) Does your household have adequate/enough food the whole year?

Yes ☐

No☐

(b) If No in (a) above, how many months in a year does your household have trouble getting enough food? _________________________________

21. (a) Do you or someone else in your household grow crops?

Yes ☐

No☐

(b) If Yes in (a) above, how long has your household been growing crops?

________________ Years ________________ Months

22. What kind of food crops does your household grow (tick where applicable)?

Maize	
Beans	
Teff	
Millet	
Pigeon peas	
Green grams	
Sorghum	
Other, specify: ………………………………………………………………. ………………………………………………………………. ………………………………………………………………. ………………………………………………………………. ………………………………………………………………. ………………………………………………………………. ……………………………………………………………….	

23. Does your household save some of the crops you harvest in order to eat at a later period?

Yes ☐

No☐

24. Does your household save seeds to plant during the next season/year?

Yes ☐

No☐

25. Do you or any member of your household participate in off farm activities (activities other than farming)?

Yes ☐

No☐

26. Do you grow any cash crops (e.g., cotton, tobacco, fruits, etc.)?

Yes ☐

No☐

Part E: Water

27. In the past year, have you heard about any conflicts over water in your community?

Yes ☐

No☐

28. Do you have access to water?

Yes ☐

No☐

29. What is the **MAIN** source of the water you use for domestic purposes (*please tick one – the main one)*?

- River☐
- Stream☐
- Spring☐
- Rock catchment☐
- Borehole ☐
- Dug well☐
- Dam☐
- Other (please specify)

  ____

30. How far is the water source from your home? _______________ Kilometres

31. How long does it take to get to your water source?

_______________ Hours _______________ Minutes

32. Is your source of water for domestic purposes available every day?

Yes ☐

No☐

33. (a) Do you store water for use?

Yes ☐

No☐

(b) How many litres of water do you store? ____

34. (a) Do you treat your drinking water?

Yes ☐

No ☐

(b) If Yes in the above, what method of water treatment do you use?

- Boiling ☐☐
- Solar
- Chlorine☐
- Ash☐
- Moringa ☐
- Filtering (cloth, sand, etc.) ☐
- Others (please specify)

____

Part F: Natural Disasters and Climate Variability

35. Has this area been affected by flooding in the past 6 years (2014-2020)?

Yes ☐

No☐

36. How many times has this area been affected by floods in the past 6 years? ________________

37. (a) Did you receive any warning about the floods before it happened?

Yes ☐

No☐

(b) If Yes in the above, where did you **FIRST** get the warning from? (*tick one*)

- Radio ☐
- Television☐
- Newspaper☐
- Government☐
- NGO☐
- Family☐
- Friend ☐☐
- Phone
- Community leader ☐
- Farming Association☐
- Others (please specify) ____________________________

38. Was anyone in your family injured in the floods?

Yes ☐

No☐

39. Did anyone in your family die during the floods?

Yes ☐

No☐

40. Did your family leave your home during the floods?

Yes ☐

No☐

42. Has this area been affected by drought in the past 6 years (2014-2020)?

Yes ☐

No☐

43. How many times has this area been affected by drought in the past 6 years? ________________

44. (a) Did you receive any warning about the droughts before they happened?

Yes ☐

No☐

(b) If Yes in the above, where did you **FIRST** get the warning from? (*tick one*)

- Radio ☐
- Television☐
- Newspaper☐
- Government☐
- NGO☐
- Family☐
- Friend☐☐
- Phone
- Community leader ☐
- Farming Association☐
- Others (please specify) ____________________________

45. What was your **<u>BIGGEST</u>** worry during the drought (*please tick one – the biggest*)?

- Lack of food☐☐
- Sickness ☐
- Lack of water
- Loss of animals and crops☐☐
- Loss of job
- Other (please specify) ___________________________________

46. Did anyone in your family die during the drought(s)?

- Yes ☐
- No☐

47. Did your family leave your home during the drought(s)?

- Yes ☐
- No☐

48. Has this area been affected by windstorms in the past 6 years (2014-2020)?

Yes ☐

No☐

49. How many times has this area been affected by windstorms in the past 6 years? ________________

50. (a) Did you receive any warning about the windstorms before they happened?

Yes ☐

No☐

(b) If Yes in the above, where did you **FIRST** get the warning about windstorms from? (*tick one*)

- Radio ☐
- Television☐
- Newspaper☐
- Government☐
- NGO☐
- Family☐
- Friend ☐
- Phone☐
- Community leader ☐
- Farming Association☐
- Others (please specify) ____________________________

51. Was anyone in your family injured in the windstorm(s)?

- Yes ☐
- No☐

52. Did anyone in your family die during the windstorm(s)?

- Yes ☐
- No☐

53. Did your family leave your home during the windstorm(s)?

- Yes ☐
- No☐

Part G: Social Networks and Empowerment

54. Did you borrow any money from relatives or friends in the past month?

Yes ☐

No☐

55. Did you lend any money to relatives or friends in the past month?

Yes ☐

No☐

56. In the past month, did relatives or friends help you and your family, and, did you or your family help relatives or friends? (**Read choices and mark all that apply**)

TYPE OF HELP	RECEIVED	GIVEN
Medical care or medicines		
Help in selling animal products and other goods produced in the family		
Transportation		
Connection to important people		
Help when someone was sick		
Help find information about something		
Get goods that are hard to get in the village		
Emotional support		
Taking care of crops		
Taking care of animals		
Fetching water or firewood		
Taking care of children		
Building house		
Other____		

57. In the past 12 months (one year), have you or someone in your family gone to your community leader or local government for help?

Yes ☐

No☐

58. Are you a member of any self-help or social group?

Yes ☐

No☐

59. Do you have access to a market where you can sell your produce or buy agricultural inputs?

Yes ☐

No☐

60. How far is the market from your home? ________________ Kilometres

61. How many grain traders are there within your village or in the nearby locality? ____________

62. (a) Do you have relatives that you rely on during critical times?

Yes ☐

No☐

(b) If Yes in the above, how many relatives support you during critical times?

SECTION C: LOCAL COMMUNITY PERCEPTION TO A CHANGING CLIMATE

1. Have you observed a difference in average temperature and rainfall during the previous 20 years? (From 2001 to 2021)? Yes No☐☐

2. If yes, how do you describe these changes? (Please put a tick (/) appropriate responses)

STATEMENT	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Rainfall amounts					
Has increased					
Has remained the same					
Has decreased					
Rainfall spacing					
Has widened					
Has Narrowed					
Has remained the same					
Rainfall time (season)					
Has Extended					
Has shortened					
Has remained the same					
Rain onset					
There is delayed rainfall onset					
Rainfall ends late					

Rainfall ends early					
Delay onset & ends early					
There is early onset					

3. Climate variability negatively affect my livestock
4. To a very great extent ( ) To a great extent ( ) To a moderate extent ( ) To a low extent
5.
6.

7. To what extent have you been facing the following conditions since 2001 due to climate variability?

Effects	**Very great extent**	**Great extent**	**Moderate extent**	**Low extent**	**No extent at all**
Droughts					
weather pattern changes					
Severe water scarcity					
Livestock pasture declining					
livestock loss					
Severe loss of pasture grass and other fodder					
Food insecurity					
Increased reliance on food aid					
Frequent crop failure					
out migration of human and livestock					
Reduced crop and livestock					

production					
Increased incidences of livestock and crop pest and diseases					

SECTION E: ADAPTATION STRATEGIES TO ECOLOGICAL AND SOCIO-ECONOMIC ACTIVITIES AS A RESPONSE CLIMATE CHANGE AND VARIABILITY

Please tick appropriately

Adaptation Strategies	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**	**Strongly disagree**	**Disagree**
Crops							
Plant early maturing crops							
Plant drought tolerant crops							
Adjust planting time							
Practice Early Planting							
Change of crop type							
Increase farm size							
Reduce farm size							
Practice crops diversification							
Measures of soil conservation							
Compost manure addition							
Crop rotation							

Contour farming							
Integrated pest management							
Cover crop							
Artificial fertilizer addition							
terracing,							
mulching							
Livestock							
Diversification of herd composition (for example rearing camels)							
Migration and herd splitting							
Slaughter old and young animals							
Destocking/ reduce the number of livestock							
Supplement livestock feeds for example with feed with root tubers							
Preservation of fodder							
Sale livestock meet other basic needs							
Reliance on fodder aid for your livestock							

Roof rain water harvesting for livestock							
Credits from better-offs, groups and credits institutions							
Sale milk and crop produces							

APPENDIX 2: RESEARCH PERMIT

12:57 27%

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