CLIMATE VARIABILITY EFFECTS ON PASTORALISM AND ADAPTATION STRATEGIES IN TURKANA CENTRAL SUB-COUNTY, KENYA

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A Thesis Submitted to the Graduate School in Partial Fulfilment for the Requirements of the Award of a Master Degree of Science in Environmental Science

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October, 2016.

DECLARATION AND RECOMMENDATION

DECLARATION

This thesis is my original work and has not been submitted for examination in any other university for the award of any degree.

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RECOMMENDATION

This thesis has been submitted for examination with our approval as university supervisors.

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ABSTRACT

Climate variability is an emerging global environmental issue of concern, posing a threat especially for pastoral livelihoods of communities in arid and semi-arid lands (ASALs), necessitating an understanding of the emerging climate variability effects on local ecosystems. This study sought to understand the effects of climate variability on pastoralism, focusing on Turkana Central Sub-County in Kenya. The specific objectives of the study were: to analyse rainfall and temperature variability for the period 1983 to 2014; to determine the effects of rainfall and temperature variability on pasture availability; to determine the effects of rainfall and temperature variability on water accessibility; and to assess the adaptation strategies to climate variability in Turkana Central. Two research designs were used in this study: longitudinal and cross-sectional designs. Stratified random sampling technique was employed to select a sample. The sample size was 100 household heads practising pastoralism within the study area. Primary data was collected through household surveys and focus group discussions (FGDs). Secondary data included Landsat images - for 1984, 2002 and 2014 - from which Normalized Difference Vegetation Index (NDVI) values were computed. Primary data was analysed using both descriptive and inferential statistics: measures of central tendency and dispersion, Spearman's correlation and Chi-square test. Results from the study indicated that there was an increase of 160.7 mm in rainfall and 0.4°C in temperature during the period 1983 and 2014. However, the study findings indicated an increase in drought duration, frequency and severity, according to 82 % of the respondents. Both pasture and water availability in Turkana Central Sub-County had increased as rainfall amounts increased and temperatures remained relatively the same over the years; the surface area covered by vegetation and water had increased by 317.9 Km^2 and 60.5 Km^2, respectively. Based on the perceptions of respondents, rainfall variability had a strong positive and significant effect on pasture availability and water accessibility ($r = 0.701$, $p < 0.00$; $r = 0.925$; $p < 0.00$). Temperature variability had a weak positive but insignificant effect on pasture availability ($r = 0.217$; $p < 0.309$), while it had a moderate positive and significant effect on water accessibility ($r = 0.357$; $p < 0.007$). The study further established that the most effective indigenous adaptation strategies were migration and herd diversification, whereas the widely adopted modern adaptation strategies were fodder provision and usage of boreholes and water tanks. In conclusion, climate in Turkana Central has become more variable, necessitating more adoption of modern adaptation strategies to mitigate negative effects of severe droughts.

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LIST OF ACRONYMS

AFORNET: African Forest Research Network

ALRMP: Arid Lands Resources Management Project

ASALs: Arid and Semi-Arid Lands

DPSIR: Drivers, Pressures, State, Impact, Responses

EAC: East African Community

GDP: Gross Domestic Product

GOK: Government of Kenya

IFRCRCS: International Federation of Red Cross and Red Crescent Societies

IGAD: Intergovernmental Authority on Development

ILO: International Labour Organization

IPCC: Intergovernmental Panel on Climate Change

KNBS: Kenya National Bureau of Statistics

NDVI: Normalized Difference Vegetation Index

NEMA: National Environment Management Authority

SDGs: Sustainable Development Goals

SID: Society for International Development

UN: United Nations

UNEP: United Nations Environment Programme

UNESCO: United Nations Educational, Scientific and Cultural Organization

CHAPTER ONE

INTRODUCTION

1.1 Chapter Summary

This chapter gives an insight to the entire study, beginning with the background information of the problem under study, through to operationalization of key terminologies relevant to climate variability and pastoralism. It gives a clear statement of the problem, stating the objectives and corresponding research questions and justification of the study. The chapter also outlines the geographic and theoretical scope of the study, assumptions made before the study and challenges experienced in the field during data collection.

1.2 Background Information

Climate variability has in the recent past become a global environmental issue of concern. In many parts of the world, climate variability is resulting in major effects on human and natural systems (Watson & Binsbergen, 2008). Over the 20th century, for instance, more global land areas experienced severe drought or severe wetness due to inter-decadal and multi-decadal climate variability (IPCC, 2001b). Vulnerability to climate variability varies from region to region. Most developing countries are especially susceptible to climatic variability because their economies are closely linked to climate sensitive sectors such as agriculture (Mendelsohn *et al*., 2006). Africa is particularly more vulnerable due to high poverty levels (Parry *et al*., 2007) and the fact that agricultural production is the primary source of livelihoods for 66% of the total active population (ILO, 2007). Even so, the frequency and intensity of droughts have increased in recent decades in the continent (IPCC, 2001b). According to World Bank (2003), 39% of people in arid and semi-arid lands live in Africa. Consequently, the continent risks becoming a major global food crisis epicentre if climate variability issues remain unaddressed at local levels (Bunce *et al.*, 2010).

Climate variability and change has been experienced in Kenya, as revealed by an analysis of rainfall patterns and temperature changes. For instance, variability in rainfall is increasing; rainfall is becoming irregular and unpredictable and more intense when it rains (GOK, 2010). A general decline in the amount of rainfall has been observed during the long rains season (March to May); frequent and prolonged droughts are experienced during this season (GOK, 2010). On the other hand, more rains have been received during September to February, extending the short rains season (usually October to December) into a previously hot and dry period of January and February (GOK, 2010). The mean annual temperature has increased by 1.0°C since 1960 and is projected to increase to 2.8°C by the 2060s (Kabubo-Mariara, 2007).

Pastoral systems provide an important source of livelihood to many people in the world. About 40 million people, almost half of them being African pastoralists, depend almost entirely on livestock for their livelihoods (AFORNET, 2005). The arid and semi-arid lands (ASALs), which constitute about 83% of Kenya, are home to more than 30 % of the human population and nearly half its livestock (Mohamed, 2013). Eleven counties in Kenya are classified as arid, 19 as semi-arid, and six as having pockets of arid and semi-arid conditions (Kirkbride, 2006). The livestock sector in the arid and semi-arid lands accounts for 90 % of employment and 95 % of household income, contributing roughly five percent of Gross Domestic Product (GDP) (Kirkbride, 2006). However, Kenya's rangelands are receding due to climate variability, threatening the livelihood and way of life of millions of pastoralists and agro-pastoralists (GOK, 2010).

Nomadic pastoralism, based on subsistence-based exploitation of shifting, grazing and browsing opportunities is central to the economy of Turkana. Livestock forms an integral part of the community's social and spiritual life. In addition to providing life-sustaining products (such as milk, blood, meat, hides, skins and ghee), goats, sheep, cattle and camels are used as payment of bride price and in local rituals. The population also relies on fishing around Lake Turkana for their livelihoods, with agricultural potential generally restricted to the hinterlands of permanent rivers, especially Turkwel and Kerio Rivers. However, Lake Turkana level has fluctuated in response to climate variability; in the past, the Lake stood 100m higher than present under wetter conditions (Dumont, 2009). Though droughts are a regular feature in Kenya's ASALs, during the past 20 years or more, the survival of nomadic pastoralism as a traditional subsistence-based livelihood strategy in Turkana has been increasingly threatened by persistent droughts and low rainfall. For example, the 1999-2001 drought in Turkana was more severe than the previous droughts of 1992-1993 and 1996-1997 (Watson & Binsbergen, 2008). Consequently, droughts now cause significant humanitarian problems and localized degradation of natural resources (ibid).

Although scientists can predict with high confidence that global average temperatures will increase by 1.4-5.8°C by the end of the twenty-first century, the regional and local scale consequences of this warming trend are much less clear (Herrmann & Hutchinson, 2007).

Yet, local impacts of global warming have profound effects on regional climatic conditions, which will in turn impact on Africa's water resources, including lakes and wetlands (UNEP, 2006). Consequently, it was crucial that the regional effects of climate variability on livelihoods be assessed. It is against this background that a study on the effects of climate variability on pastoralism and adaptation strategies in Turkana Central was conceived.

1.3 Statement of the Problem

In the last few decades, droughts and floods have claimed lives of thousands of people and livestock in the Turkana Central Sub-County, Turkana County. Most of these droughts have been declared national disasters by the Kenyan government and thus the need for immediate humanitarian relief from both the private and public sector. The prolonged episodes of droughts and floods, which have in part been attributed to climate variability, have greatly contributed to food insecurity and frequent inter-ethnic and clan conflicts over use of natural resources in the region. The study, therefore, assessed the effects of climate variability on pastoralism and the adaptation strategies in the region.

1.4 Study Objectives

1.4.1 Broad Objective

To assess the effects of climate variability on pastoralism and adaptation strategies so as to enhance food, water and economic security in Turkana Central Sub-County.

1.4.2 Specific Objectives

The specific objectives of the study were:

i) To analyse rainfall and temperature variability in Turkana Central for the period 1983 to 2014.
ii) To determine the effects of rainfall and temperature variability on pasture availability in Turkana Central.
iii) To determine the effects of rainfall and temperature variability on water accessibility in Turkana Central.
iv) To assess the adaptation strategies to rainfall and temperature variability in Turkana Central.

1.5 Research Questions

The questions to which the study sought to provide answers for were:

i) What variability in rainfall and temperature has been experienced in Turkana Central in the period 1983 to 2014?

ii) What are the effects of rainfall and temperature variability on pasture availability in Turkana Central?

iii) What are the effects of rainfall and temperature variability on water accessibility in Turkana Central?

iv) Which are the adaptation strategies to rainfall and temperature variability within Turkana Central?

1.6 Justification of the Study

Floods and droughts are the world's most destructive natural disasters, causing an average \$6–\$8 billion in global damages annually and collectively affecting more people than any other form of natural disaster (Vasiliades *et al.*, 2009). The main source of livelihood for the Turkana community is pastoralism, which is dependent on favourable climatic conditions for water and pasture availability. However, trends of more frequent and severe droughts, and recently floods, have been reported within the region. According to IFRCRCS (2010), prolonged drought in 2009 affected over 3.8 million people in pastoral, agro-pastoral and marginal agricultural areas in Kenya and floods displaced 436 households in Turkana Central in 2010. This scenario, which has in part been attributed to climate variability, is exacerbating the already acute food shortage due to livestock deaths. Consequently, people often die of hunger and malnutrition.

This study therefore sought to assess the effects of climate variability on pastoralism, and the extent of adoption of both indigenous and modern adaptation strategies, with a view of contributing towards the establishment of proactive mitigation strategies instead of the common reactive post-disaster emergency humanitarian aid. The findings of the study highlighted the major effects of climate variability on the major source of livelihood for this marginalized community, which if addressed will enhance the achievement of the first, second, sixth and thirteenth Sustainable Development Goals (SDGs) - ending poverty, achieving food and water security as well as combating climate change. The study findings are beneficial especially to Turkana County Government in realizing Kenya Vision 2030. By encouraging adoption of effective and efficient pasture-related modern adaptation strategies, the Government will enhance livestock production, and thus contribute towards realization of the economic pillar of maintaining a sustained economic growth of 10 % per annum. Under the social pillar of the Vision, one of the aims is to ensure availability and accessibility of improved water to all, by inventing new ways of harvesting rainwater – one of the recommendations of this study.

1.7 Scope, Assumptions and Limitations of the Study

1.7.1 Scope of the Study

The study was confined to Turkana Central Sub-County, Turkana County, in Lake Turkana Basin, Kenya. The sampling sites included Kapua, Kang'atotha, Napetet and Kanamkemer locations in Kalokol and Central divisions. The study focused on the effects of climate variability on pastoralism, and assessment of the existing adaptation strategies to mitigate these effects. Thus, rainfall and temperature data for the period 1983 to 2014 was analysed for variability. Landsat images for the years 1984, 2002 and 2014 were also processed and analysed to obtain Normalized Difference Vegetation Index (NDVI) values. In addition, questionnaires were administered to local residents who practised pastoralism. The study was undertaken for a period of fifteen months.

1.7.2 Assumptions of the Study

The following assumptions were made about the study:-

1. There would be trends in rainfall and temperature patterns in Turkana Central. This would then provide data for assessing frequency of climate extremes – droughts and floods – and the consequent effects on pasture and water availability in the study area.
2. The pastoralists constituting the sample had comprehensive knowledge of rainfall and temperature variability and their effects on pastoralism, which would be sufficient to draw conclusions about the entire population.

1.7.3 Limitations of the Study

The limitations experienced during the study were as follows:

1. Rainfall and temperature data from Kalokol Station was not obtained, as earlier intended, since the station was no longer operational. Thus, data from Lodwar Meteorological

Station only was used to make inferences about climatic conditions of the study area. More data of Lodwar Station was acquired from Kenya Meteorological Department, Nairobi. Nonetheless, some temperature data was missing, notably minimum temperature data for 1983 and 1986; temperature data from which inferences were made was 92 % complete.

2. Most respondents had an incorrect perception about rainfall trends over the period under study. Thus, the correlation coefficient and Chi-square values computed, based on these perceptions, did not give a true reflection of the effect of rainfall variability on both pasture availability and water accessibility in the region.

1.8 Definition of Terms

Adaptation: The measures, actions and initiatives that people take to reduce the vulnerability of natural and human systems against actual or expected climate variability effects.

Climate change: A change in the state of climate that can be identified (for example using statistical tests) by changes in the mean and/or the variability of its properties. It persists for an extended period, typically decades or longer (IPCC, 2012).

Climate variability: Variations in the mean state and other statistics (such as standard deviations and occurrence of extremes) of climate on all temporal and spatial scales beyond that of individual weather events (IPCC, 2012).

Food security: A situation that exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

Livelihood: The capabilities, assets (including both material and social resources) and activities required for a means of living (Krantz, 2001).

Mitigation Human intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC, 2014).

Pastoralism: A predominantly livestock-based production system in rangelands, where free-range grazing and seasonal migration is practised in search of pasture and water for livestock, determined by rainfall patterns and dynamic external conditions.

Pasture availability: The presence of forage, measured in terms of vegetation surface area coverage and distance from households to pasture lands.

Rainfall variability: The degree to which rainfall amounts at a given location vary through time; temporal rainfall variability.

Remote sensing: The science of obtaining information about objects or areas on the Earth's surface from a distance, typically from satellites or aircrafts.

Temperature variability: The degree to which temperatures experienced at a given location vary through time; temporal temperature variability.

Water accessibility: The availability of water for use when needed, measured in terms of distance from household to water source.

Water security: The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability (UN, 2013).

CHAPTER TWO

LITERATURE REVIEW

2.1 Chapter Summary

The literature review section gives an in-depth review of previous studies related to climate variability, highlighting the research gaps that the study intended to fill. The major sub-sections discuss climate variability, its effects and adaptation strategies adopted by communities in regions similar to the study area. An illustrative conceptual framework showing the independent, dependent and intervening variables of the study concludes this section.

2.2 Global and Regional Climate Variability

Climate variation, whose frequency in terms of temperature and rainfall has been increasing over the years, manifests itself in extended drought, floods and conditions that result from periods of El Nino and La Nina events (Chibinga *et al*., 2012). Although the effects of future global climate variability for pastoralists are uncertain, a decrease in the amount and predictability of rainfall and warmer temperatures are likely to be experienced (Birch & Grahn, 2007).

2.2.1 Rainfall Variability

According to Meier *et al*. (2007), inter-annual variability of rainfall has been increasing globally. In addition, large regional differences exist in rainfall variability (Hulme *et al*., 2001). In some regions, different climate models project different trends in wet and dry extremes, while in other regions the models show clear trends of either wetness or dryness (Herrero *et al*., 2010). According to IPCC (2001b), scenarios for summer rainfall in the Sahel region vary by as much as +/- 20%. The changing climate is expected to increase the frequency and intensity of drought and flood events in the coming years (UNEP, 2010).

Most lakes in Africa are located in the Great Rift region, making them susceptible to earthquakes and volcanic eruptions, which can cause flooding. On the other hand, chances of drought in parts of the Greater Horn of Africa have doubled from one in five years to one in three years (Meier *et al*., 2007). East Africa appears to have a relatively stable rainfall regime, but there is likely to be an increase in annual mean precipitation resulting in increasing floods (Christensen *et al*., 2007).

Kenya, despite its location along the equator faces extreme variations in climate due to its various landforms, particularly the Rift Valley. Rainfall is highly variable, with the long rains (March–May) being less variable; inter-annual variability is related primarily to fluctuations in the short rains (Herrero *et al*., 2010). Similarly, Ethiopia faces a heightened vulnerability to these extreme weather events. According to the International Disasters Database, in the last 30 years Ethiopia has experienced 9 periods of droughts and 43 floods.

The Intergovernmental Panel on Climate Change (IPCC) has made numerous documentations on global rainfall trends. However, knowledge of changes in climate extremes is sparse, particularly for Africa (Herrero *et al*., 2010). Moreover, the sign of changes in mean precipitation in many parts of Africa varies across climate models (Challinor *et al.*, 2007). This study, thus sought to provide data on rainfall variability for the period 1983 to 2014 in Turkana Central Sub-County, in East Africa. This data, if utilized, would aid in prediction of droughts and floods, enhancing preparedness within the region.

2.2.2 Temperature Variability

According to IPCC (2001b), global warming has been experienced, with Africa's climate being warmer than it was 100 years ago; periods of most rapid warming occurred in the 1910s to 1930s and the post-1970s. The Intergovernmental Panel on Climate Change (IPCC) predicted that air temperature will rise by 2-4°C by the end of this century, but the actual air temperature increase in the Far East for the last decades is almost double this prediction (Goldman *et al.*, 2013). Nonetheless, rising greenhouse gas concentrations from human activities are expected to cause more rapid changes in the Earth's climate than have been experienced for millennia (UNEP, 2006).

During this century, the East African climate is expected to warm across all seasons (IPCC, 2007). Annual mean surface air temperatures are expected to increase between 3°C and 4°C by 2099 in the region, rising at a rate roughly 1.5 times the global average (ibid). Kenya's mean annual temperature increase, of 1.0°C since 1960, has been higher from March to May, resulting in an increase in the number of hot days and hot nights (McSweeney *et al.*, 2008). Notwithstanding, these mean annual temperatures are expected to further increase by 1.0°C to 2.8°C by the 2060s, and 1.3°C to 4.5°C by the 2090s (ibid). Rising temperature levels will potentially lead to higher rates of evapo-transpiration, thus, minimising the impact of rainfall (Campbell *et al.*, 2009).

Temperature projections vary across Africa: of three macro-regions of Sub-Saharan Africa (East, West and Southern) reviewed, only the Western region showed consistent temperature projections across the climate models (IPCC, 2001a). Moreover, recent studies show conflicting evidence for different parts of Africa, such as the Sahel (Challinor *et al.*, 2007) Hence, the aim of this study was to give regional data on variability in temperature over the last three decades, with a focus on Turkana Central Sub-County, which falls within East Sub-Saharan Africa. Regional projections can be made, based on this data, to facilitate preparedness in anticipation of extreme temperatures and related natural disasters.

2.3 Global and Regional Climate Variability Effects

Climate variability effects materialize through changes in extreme events such as droughts and floods. According to Herrero *et al*. (2010), such extremes hamper economic development and efforts at poverty reduction and result in severe human suffering. Maitima *et al.* (2009) elaborates that the effects of climate extremes are measured not only by direct economic damages and lives lost but also by the effects on livelihoods and development. More droughts and floods reduce agricultural production, especially for subsistence farmers at low latitudes (UNEP, 2006). The variability in rainfall and temperture are also expected to have most damaging effects in the already hot and dry tropical and sub-tropical areas (Droogers & Aerts, 2005). Sub-Saharan Africa (SSA), for example, is predicted to be particularly hard hit by global warming because it already experiences high temperatures and highly variable low precipitation (Kabubo-Mariara, 2007). According to UNEP (2010), the total economic damage costs due to three major droughts in Ethiopia, since 1969 are estimated at US$92.6 million. With close to half of Ethiopia's GDP attributable to the agricultural sector, managing food and economic security in the face of an uncertain climate continues to be an issue (UNEP, 2010). The highly variable rainfall received in Kenya, especially in the arid and semi-arid regions, is unreliable for livestock production (Herrero *et al*., 2010).

2.3.1 Water Accessibility

Climate variability and change have important implications on the hydrologic cycle. Inland water form hydrological ecosystem networks that spread over the earth, and changes occurring in lakes, rivers and wetlands of these provide key information to measure and understand the effects of climate variability and change on land as well as on aquatic ecosystems (Goldman *et al.*, 2013). Climate variability is expected to have a great influence on river discharge and lake ecosystems within catchment areas (UNEP, 2010). Indeed, climate reports from the Inter-governmental Panel on Climate Change (IPCC) and other national and international climate assessments conclude that freshwater systems are especially vulnerable to climate variability and change. The Fourth Assessment Report notes that climate variability and change will lead to changes in all components of freshwater system and include effects on water availability, timing, quality and demand (Gleick, 2012).

The natural variations of climate are the main reason for the alteration in water balances of both terminal lakes and their basins. The reduction of lakes will lead to serious ecological and socio-economic problems of environmental origin (Awange & Obiero, 2006). According to Wit and Stankiewicz (2006), the effect of climate variability and change on Africa's hydrological resources will be felt in three main hydrological regions: dry, intermediate and wet. In the intermediate region, receiving between 400-1000mm of rain per year, the effect of climate variability and change on surface drainage will be greatest. Drier areas within this range will also experience significantly great losses in surface drainage. This will have devastating consequences for this intermediate hydrological zone, which covers 25% of the continent, affects 75% of the 48 mainland countries in Africa and includes most of the densely populated savanna rangelands of southern and eastern Africa and a significant part of the Sahel (Wit & Stankiewicz, 2006). The decrease in surface drainage coupled with an increase in water demand by livestock and people, as a result of increased temperatures, will challenge traditional coping strategies and likely increase tensions around already scarce water resources (ibid).

Lake Turkana is a classical example of the effect of climate variability and change on surface drainage. Six thousand five hundred years ago, it was a freshwater lake five times its present size, its water level nearly 100 metres higher than today (Avery, 2014). Its waters were spilling into the Nile Basin that is about 150 km northwest of the present lakeshore. However, as the region became increasingly arid, the lake level dropped and the basin closed with no outlet, thereafter becoming progressively more saline (Avery, 2014). Prolonged drought contributed to the lake's decline in water level and volume (Hathaway, 2010).

Owing to the fact that Lake Turkana is one of the major sources of water for livestock in Turkana Central, with most rivers drying up and water volume decreasing in perennial rivers and aquifers during dry seasons, this study sought to investigate the effects of rainfall and temperature variability on water accessibility in the region.

2.3.2 Pasture Availability

Rangeland productivity is mainly determined by rainfall and temperature. Rainfall is very important for pastoral systems as it determines the distribution, amount and quality of pasture (Birch & Grahn, 2007). However, climate variability over the years has negatively affected the ability of local ecosystems to meet the ever increasing demand for feed resources for livestock; sustainability of pastoral systems has been facing a lot of challenges in Africa especially in terms of availability of adequate animal feed resources (Chibinga *et al*., 2012). In the Horn of Africa, millions of people currently live a lifestyle that is centred on the search for the increasingly scarce pasture (Ehrhart, 2009). When pastoralists lose their livelihoods, through loss of access to pastures, they become destitute and conflicts over resources arise (Omolo, 2010).

Climate variability, which has led to increased droughts and floods, has resulted in the loss of animal lives (Omolo, 2010). When successive rainy seasons fail, there is insufficient regeneration of grazing land, and areas under pastures reduce. Pastoralist communities from Kotido in north-eastern Uganda report such a case, explaining that the long rains that used to occur between March - August are now beginning as late as May (Kirkbride & Grahn, 2008). Increasing temperatures lead to soil degradation, through lose of soil water and microbial biodiversity, thus reducing the ability of ecosystems to sustain growth (Maitima *et al.*,2009). Since pasture availability is highly dependent on favourable climate, yet crucial for sustainability of the major source of livelihood in Turkana Central, it was vital that this study assessed the effects of rainfall and temperature variability on pasture availability in the region.

2.4 Global and Regional Climate Variability Adaptation

Climate variability adaptation strategies are very crucial to ensure resilience of livelihoods and economies. Self reliance realised through effective pre-disaster and adaptation planning, as an integral part of development and aimed at capacity building for the most vulnerable, is a more effective means of disaster risk reduction (Maitima *et al.*, 2009). Although adaptation is perceived as being very important to protect societies against the effects of climate variability, the statistics reveal a disproportionate impact in developing countries and on less-favoured populations (Burton *et al*., 2006).

Pastoralists have diverse possible adaptive responses available to deal with climate variability. These include technological options (such as more drought-tolerant livestock breeds), behavioural responses (such as changes in dietary choice), managerial changes (such as different livestock feeding practices), and policy options (such as planning regulations and infrastructural development) (Thornton *et al.*, 2010). Herding communities in ASALs migrate with their animals in search of pasture and water, and reserve some pastures back at their homesteads for grazing by vulnerable animals left under the care of women during migration seasons (Herrero *et al*., 2010). These herders also vary their animal herds in terms of the composition, size and diversity to suit their variable feed resources, in order to protect them against droughts that could otherwise wipe out their animal stock (Herrero *et al*., 2010). Keeping multispecies herds enables the pastoralists take advantage of the different ecological niches of the different livestock species (Chibinga *et al*., 2012).

This study, thus, sought to assess the extent to which pastoralists within Turkana Central Sub-County had adopted these indigenous adaptation strategies. In addition, its aim was to establish whether the local Turkana community had incorporated modern scientific adaptation strategies to ensure resilience of their major source of livelihood.

2.5 Policy Frameworks

Sustainable Development Goals

Food and water security, in the face climate variability and change, is essential for the sustainable development of all countries. The first, second, sixth and thirteenth Sustainable Development Goals (SDGs) - no poverty; zero hunger; clean water and sanitation; and climate action – seek to ensure this. The fifth target of the first goal envisions that by 2030, the resilience of the poor and those in vulnerable situations should have been built and their exposure and vulnerability to climate-related extreme events, environmental shocks and disasters reduced (UN, 2015). The fourth target of the same goal stipulates that by 2030 all men and women, in particular the poor and the vulnerable, should have access to basic services, ownership and control over land and other forms of property, inheritance, natural resources and appropriate new technology (ibid).

The second goal aims that by 2030 there will be sustainable food production systems and implementation of resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters (UN, 2015). The sixth goal advocates for universal and equitable access to safe and affordable drinking water for all by 2030. This will be enhanced by implementation of integrated water resources management at all levels, including through transboundary cooperation (ibid). Lake Turkana is a transboundary water resource, necessitation cooperation between Kenyan and Ethiopian governments to ensure efficient management.

The thirteenth goal, on taking urgent action to combat climate change and its impacts, vouches for strengthening resilience and adaptive capacity to climate-related hazards and natural disasters in all countries (UN, 2015). Integrating climate change measures into national policies, strategies and planning would provide legal frameworks on the national scales. In addition, improving education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning would improve the preparedness of local people in anticipation of climate-related disasters (Osborn, *et al*., 2015).

Environmental Management and Co-ordination Act (EMCA), 1999

This Act, enacted by the Parliament of Kenya, echoes the fifth target of the sixth Sustainable Development Goal; it puts forth the principle of international co-operation in the management of environmental resources shared by two or more states (GOK, 1999). Specifically, it stipulates that environmental impact assessments should be done before storage dams and barrages are constructed (ibid). It also states that an environmental conservation order may be imposed on burdened land so as to preserve the quality and flow of water in a dam, lake, river or aquifer (GOK, 1999). In the case of construction of dams along River Omo in Ethiopia and River Turkwel in Kenya, that feed the transboundary Lake Turkana, proper consultation between the two countries was crucial to avoid negative ramifications on the Lake's levels.

National Climate Change Response Strategy

Natural disasters associated with climate variability and change in the past have cost Kenya huge losses, especially during the 1999 and 2000 droughts where damages incurred were equivalent to 2.4% of the Gross Domestic Product (GOK, 2010). Consequently the Kenyan Government formulated the National Climate Change Response Strategy in the year 2010. This strategy puts forth sectoral mitigation and adaptation strategies to climate variability and change. As a mitigation measure, Kenya aims at growing 7.6 billion trees by 2030 through agro-forestry - especially tree-based intercropping – and other tree-planting initiatives suggested under the forestry development plan (ibid). Adaptation strategies proposed for pastoralism sector include breeding of animals that adapt well to climatic vagaries and carrying out awareness campaigns among pastoral communities to emphasize the importance of keeping stocks proportionate to the available land resources holding capacity, so as to ensure sustainable pastoralism (GOK, 2010). Strategies proposed for the water sector encompass an integrated approach to water resource management and utilization, for instance, through construction of dams and water pans.

Water Act, 2002

Fair utilization of trans-boundary waters is essential to avoid conflicts among the nations sharing the resource. The Water Act, enforced in Kenya, provides for the formulation of a national water resources management strategy to govern management, conservation, protection and usage of water resources of Kenya (GOK, 2002). This strategy acknowledges that there is a lack of accurate knowledge with respect to the state of the water resources within the shared basins and the probable future demands of other riparian states – Ethiopia, Uganda, Tanzania and Somalia (GOK, 2006). Consequently, the states sharing trans-boundary waters will be concerned about threats to sovereignty, especially when another country (particularly, but not necessarily upstream) is deemed to have that information and is thus perceived as being privileged (ibid). Measures put forth to ensure equity in exploitation of shared international water courses include improving collaborative water resource management and integrating relevant international conventions and treaties governing the management of international waters into national legislation and policy (GOK, 2006).

2.6 Summary of Research Gaps

Previous researches have concentrated on studying climate variability on global and macro scales. The predictions about climate parameters vary with the different climate models used by the past studies. Additionally, different agro-ecological and climatic zones respond differently to variability in climate, necessitating adoption of varying adaptation strategies that are zone specific. It was therefore crucial that a micro-scale perspective of the rainfall and temperature trends was assessed to give accurate and precise effects of climate variability on pasture availability and water accessibility in the predominantly pastoral arid and semi-arid Turkana Central. This would enhance adoption of more zone-specific adaptation strategies, thus building the resilience of the vulnerable pastoralists to climate extremes.

2.7 Conceptual Framework

The dependent variable in this study is pastoralism, manifested by pasture availability and water accessibility. It depends on other variables including rainfall variability and temperature variability (independent variables). Intervening variables are water resource development projects (such as damming in Turkwel and Omo Rivers), charcoal production within the study area and government policies, as they compound or reduce climate variability effects. In response to these effects, the pastoralists adopt indigenous and modern adaptation strategies (Figure 2.1).

The conceptual framework was based on Drivers, Pressures, State, Impact, Responses (DPSIR) Framework. It was perceived that human demand for energy and other amenities (drivers), led to exploitation of natural resources and emission of greenhouse gases (pressures): accumulation of greenhouse gases caused global warming. As a result climate variability was experienced, that affected the quality of water and vegetation resources and their ability to support livestock and human populations (state). Consequently, livelihoods were compromised, leading to human and livestock deaths (impact). Ultimately, pastoralists and relevant agencies adopted adaptation strategies to mitigate and solve the effects of climate variability on pasture availability and water accessibility (responses).

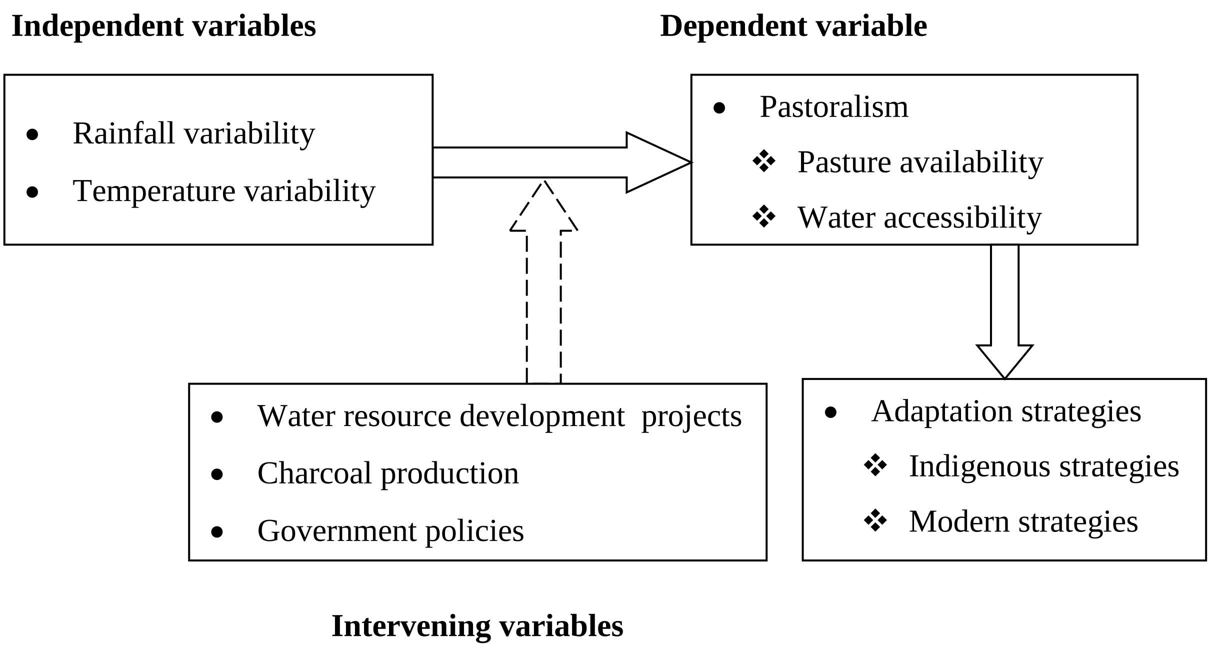


Figure 2.1 Conceptual framework

Source: Modified from Drivers, Pressures, State, Impact, Responses (DPSIR) Framework

Rainfall variability has an effect on water availability and, consequently, pasture availability. Prolonged droughts lead to extreme shortage of the already scarce water resource, which is needed for watering livestock. Since water availability is also crucial for vegetation abundance, decreased precipitation inhibits growth of pasture. This increases the number of livestock deaths. Floods, on the other hand, destroy vegetation and drown livestock. The high velocity at which water flows during floods causes lodging of plants, after which the plants rot on the ground. Considering that very few areas within Lake Turkana area support growth of pastures, the effect of intense and more frequent floods exacerbate fodder and food scarcity.

Temperature variability also has an effect on the hydrological cycle and lifespan of plants. High temperatures result in high evaporation rates from the water bodies, high transpiration rates from vegetation and high perspiration rates from reared livestock. Increased evaporation rates from the few water bodies within the study area, worsen water shortage and subsequently pasture scarcity. High transpiration rates cause wilting of vegetation, further exacerbating forage scarcity.

CHAPTER THREE

METHODOLOGY

3.1 Chapter Summary

This section begins with a detailed description of the study area, giving the geographic and socio-economic characteristics of the region. The research designs that were employed, in addition to population targeted and the procedure of selecting sampling units, are discussed. Subsequent to data collection methods that were used during the study, statistical data analysis tools are explained.

3.2 Study Area

3.2.1 Geographic Location and Size

Turkana Central Sub-County is located in north western Kenya within Turkana County, which borders Uganda to the west, South Sudan to the north and Ethiopia to the north-east (Figure 3.1). It is a 5,269 km^2 arid and semi-arid region to the west of Lake Turkana, within the Great Rift Valley. The area borders the following sub-counties: Turkana North to the north; Turkana West to the north-west; Loima to the west; Turkana South to the south; and Turkana East to the south-east.

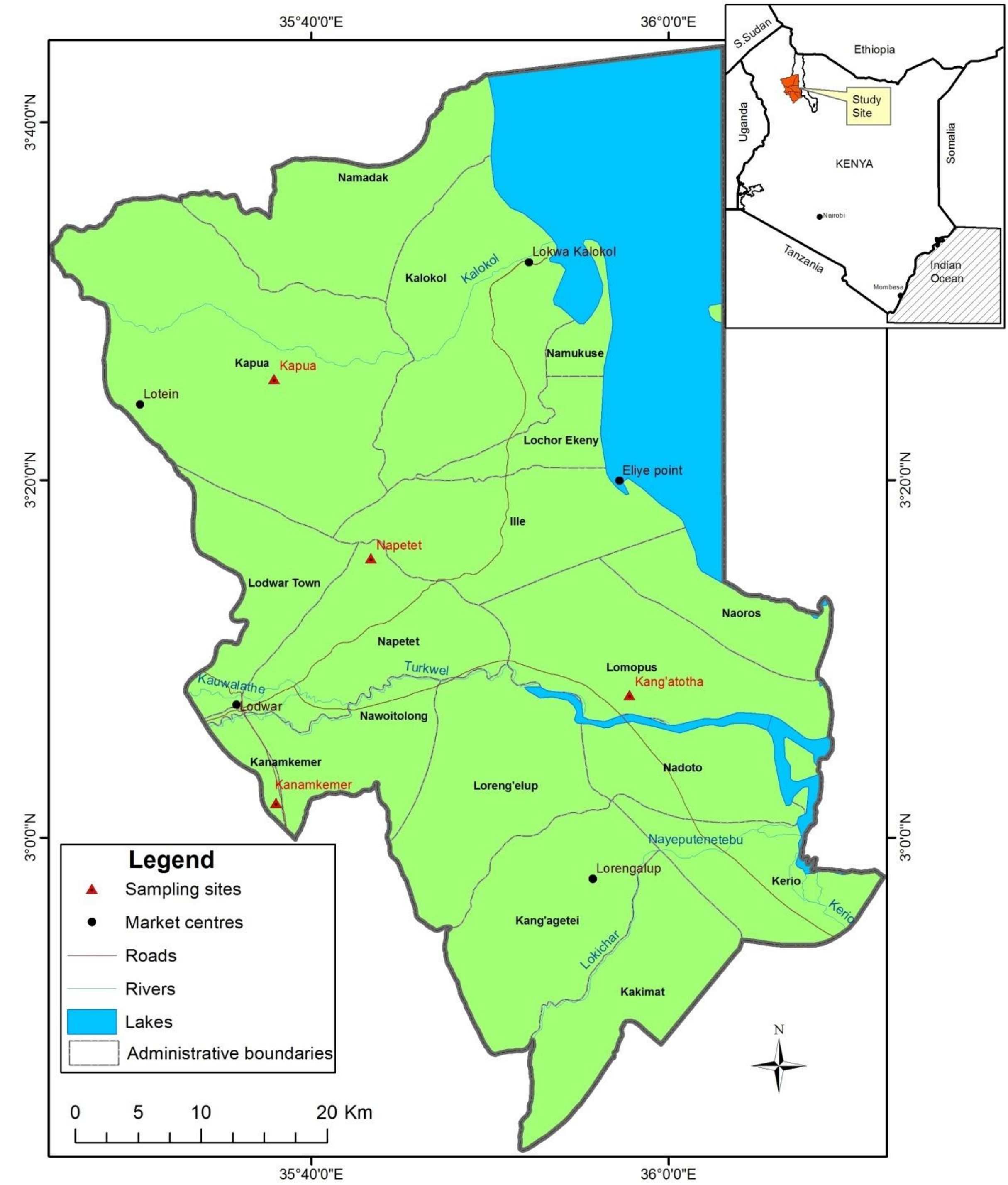


Figure 3.1: Map of the study area

Source: Regional Centre for Mapping of Resources for Development, Nairobi.

3.2.2 Topography and Geology

The area lies at an altitude of about 523m to the west, and then falls to 369m at the shores of Lake Turkana in the east (Ouma *et al*., 2012). The main geological features characterizing the area are volcanic and sedimentary rocks. Other topographical features consist of plateaus, low lying plains with isolated hill ranges, minor scarps, foot slopes, footbridges, seasonal rivers, River Turkwel and Lake Turkana (Ouma *et al*., 2012). Lake Turkana, located at about 3° N and 36° E, is the largest desert lake in the world, the largest lake in eastern Rift Valley, the fourth largest lake by volume in Africa and the most saline in East Africa (Beadle, 1981).

3.2.3 Climatic Conditions

Turkana Central, lying in agro-climatic zone V/VI-1 (Oduor *et al*., 2012), experiences a hot and dry climate. Temperatures in the region are between 24°C and 38°C, with a mean of 30°C (ALRMP, 2005). The average precipitation ranges from 121mm in the east to over 540mm in the northwest (Watson & Binsbergen, 2008). Rainfall, though erratic and unpredictable, mainly occurs in two seasons. The long rains occur between March and July, with a peak in April. On the other hand, the short rains fall from October to December, with a lesser peak in November or December (Watson & Binsbergen, 2008). The western parts and areas of higher elevation in the region receive more rainfall (Ouma *et al*., 2012).

3.2.4 Socio-economic Characteristics

The Turkana rely on nomadic pastoralism as their major source of livelihood; they keep goats, sheep, camels, cattle and donkeys. The local community in the region also practises fishing in Lake Turkana. The lake’s semi-saline waters support Africa’s highest salinity fisheries, being home to many species of fish, ten of which are endemic to the lake (Avery, 2014; Avery, 2010). Some of these fish species include *Tilapia zillii, Sarotherodon niloticus*, *Clarias lazera*, *Barilius niloticus*, *Sarotherodon galilaeus*, *Alestes nurse*, *Micralestes acutidens*, *Chelaethips bibie*, *Haplochromis rudolfianus* and *Aplocheilichthys rudolfianus* (Avery, 2010). The community also relies on the lake as a primary source of water, with the shoreline acting as grazing areas (Hathaway, 2010). However, Turkana County at large faces both physical and economic water scarcity (Oduor *et al.*, 2012). Flood-crop farming along River Turkwel and other streams is the other alternative source of livelihood, in addition to basketry, charcoal selling, firewood selling and other small trades. Tourist attraction sites in the region include ruins in Lodwar town where the first President of Kenya and other political leaders were jailed by colonialists; Namoratung'a sacred site; Central Island National Park – a UNESCO-listed World Heritage Site; and Lake Turkana.

3.2.5 Demographic Characteristics

Turkana Central is predominantly inhabited by the Nilotic ethnic Turkana Community. A summary of human population and household statistics of the region, adapted from a KNBS and SID publication (Ngugi *et al*., 2013), is illustrated in the Table 3.1.

Table 3.1: Turkana Central Sub-County population description summary

Assembly Ward	Total Population	Male	Female	Households
Kalokol	19,386	9,420	9,966	3,365
Kang'atotha	22,687	11,226	11,461	3,505
Kanamkemer	22,726	10,807	11,919	4,011
Lodwar Township	31,823	15,589	16,234	6,282
TOTAL	**96,622**	**47,042**	**49,580**	**17,163**

Source: Kenya National Bureau of Statistics & Society for International Development, 2013.

3.3 Research Design

The study employed two research designs: longitudinal and cross-sectional designs. The longitudinal design was appropriate in tracking the changes in pasture and water availability over time and relating them to changes in rainfall and temperature. It was used to describe the patterns of change and establish the direction and magnitude of the causal relationships. The cross-sectional design was suitable to describe and explore the nature and influence of the main effects of rainfall and temperature variability on pasture availability and water accessibility during the study period in Turkana Central Sub-County. As part of the latter design, the researcher employed participant observation and undertook a field survey to obtain opinions of pastoralists.

3.4 Sampling Frame

The target population of the study consisted of the Turkana community in Turkana Central Sub-County, Turkana County. The sampling frame was a list of households living within

Kalokol and Central Divisions. The household respondents were selected from a list generated using the county population statistics specifically targeting the study area. The respondents were local community members, aged above 39 years, who practised pastoralism.

3.5 Sampling Procedure

Stratified random sampling method was used to select a sample within Turkana Central Sub-County. The broad strata were Kalokol and Central Divisions. Two assembly wards were chosen in each division. A specified number of household heads from each ward were then drawn, using simple random sampling, to constitute the sample. This was done proportionately, where the number of subjects chosen was proportionate to the population in the assembly ward, in relation to the total population (illustrated in Table 3.1). In Kalokol Division, respondents were chosen from Kapua location in Kalokol Ward and Kang'atotha location in Kang'atotha Ward. In Central Division, respondents from Kanamkemer location in Kanamkemer Ward and Napetet location in Lodwar Township Ward constituted the sample. This stratified technique was preferred for the study as it provided a chance of participation to different respondents from the two divisions.

The sample size was determined using the formula put forth by Nassiuma (2000):-

$$n = NC^2 / (C^2 + (N-1)\, e^2)$$

Where n is the sample size; N is the population size 96,622; C is the coefficient of variation (30%) and e is the margin of error (3%).

Therefore, the sample size was calculated as follows:

$$n = 96{,}622*0.3^2 / (0.3^2+96{,}621*0.03^2) = 99.9 \approx 100$$

Consequently, 100 household heads were included in the sample. The proportionate distribution of these respondents per sampling site was as follows: Kapua 20, Kang'atotha 23, Kanamkemer 24 and Napetet 33.

3.6 Ethical Considerations

Written permission to undertake data collection in the study area was granted by Director of Board of Postgraduate Studies, Egerton University. Consent was sought from and granted by Turkana County Director of Agriculture and chiefs of the locations constituting sampling sites. Respondents' consent was also obtained, and only pastoralists willing to participate in the study were involved. Respondents who were not comfortable answering certain questions were not forced to give their responses.

3.7 Data Collection

3.7.1 Primary Data

Primary data was collected through household surveys and focus group discussions. Questionnaires with open and close-ended questions (Appendix I) were administered to the household heads of the local Turkana community to obtain information on the effects of climate variability on pasture availability and water accessibility, and the extent of adoption of adaptation strategies by the local community within Turkana Central. During the study, probing was also incorporated to obtain a great depth of response. Key informants from institutions whose mandates cover livestock and water resources in Turkana County and village elders constituted two focus group discussions; twelve informants in a discussion at Kapua and nine informants in a discussion in Lodwar (questions' list in Appendix II). The institutions were Ministry of Agriculture, Department of Livestock and Water Resources Management Authority.

Additionally, photographs of the different livestock types reared, pastures and water sources in the study area were taken during the study period. Varied indigenous and modern adaptation strategies and the accompanying infrastructure were also photographed. The use of photographs augmented findings from other data collection procedures.

3.7.2 Secondary Data

Secondary data on monthly rainfall and temperature, from the year 1983 to 2014 for Lodwar station was collected from Kenya Meteorological Department, Lodwar and Nairobi offices. It was essential to collect data for this period, 32 years, so as to ensure a comprehensive assessment of the parameter under study, climate. Data was also collected from other published and unpublished official sources, including books, journals, articles, reports and periodicals on the fields of climate variability and pastoralism. Landsat images for the years 1984, 2002 and 2014 were obtained from Regional Centre for Mapping of Resources for Development.

3.8 Reliability and Validity

The questionnaires were pre-tested to determine their reliability. Thirty questionnaires were administered to household heads involved in pastoralism in Baringo County. Subsequently, the concerns raised about the clarity and suitability of different questions were addressed before the study. After data collection, questionnaires were checked to ensure that all questions were answered correctly and consistently. Verification of any missing information was undertaken and explanations given for inferences made based on incomplete data, to enhance validity of the research instruments, and thus of the study findings.

3.9 Data Analysis

The data was analysed using descriptive and inferential statistics. Descriptive statistics included a measure of central tendency (mean) and measure of dispersion (range). The mean rainfall and temperature for the period 1983 to 2014 were determined. Additionally, the mean rainfall and temperature for the periods 1983-1998 and 1999-2014 was calculated, to analyse the changes in these two climate parameters over the thirty-two years. Inferential statistics were used to show the relationship between climate variability and pastoralism. These included Spearman's correlation and Pearson's Chi-square test. Spearman's correlation was used determine the strength of rainfall and temperature variability relationship with pasture availability and water accessibility. Pearson's Chi-square test, on the other hand, was used to assess the significance of the relationship between the variables; the level of significance was tested at alpha = 0.05.

The Landsat images were first processed, then classification and analysis was undertaken. The data acquired was partially processed; geo-referenced with absolute co-ordinates. The recommended land cover mapping band combination was done: bands 2 and 3 in the visible range and band 4 in the infra-red region. These three bands gave a false colour composite. Thereafter, three images were mosaiced: P 170 57, P 170 58 and 169 58. Subsetting was undertaken to remain only with the image covering the area of study. As a final processing step, image enhancement, in terms of colour enhancement and contrast, was done. Arc GIS 10.2, Idrisi Kilimanjaro and ERDAS Imagine softwares were used to process the data. Unsupervised classification was undertaken, where four classes of features were identified: vegetation, water, bare ground and rocks. Signatures of the features were first created, maximum likelihood classification command executed to encompass each feature within a signature range, and training sites finally created. Maps for three years – 1984, 2002 and

2014 – based on the four classes identified, were designed. Areas under each class were computed, as shown in Table 2.1 below. Normalized Difference Vegetation Index (NDVI), a remotely sensed vegetation index, data was also used to determine the greenness and thus the phenology of vegetation in the study area over the three decades.

Table 3.2: Summary of data analysis

OBJECTIVES	VARIABLES	STATISTICAL TOOLS
i) To analyse rainfall and temperature variability in Turkana Central for the period 1983 to 2014.	• Rainfall trends • Temperature trends	• Descriptive statistics ❖ Measures of central tendency and dispersion
ii) To investigate the effects of rainfall and temperature variability on pasture availability in Turkana Central.	• Pasture availability • Rainfall variability • Temperature variability	• Descriptive statistics • Spearman's correlation • Chi-square test
iii) To assess the effects of rainfall and temperature variability on water accessibility in Turkana Central.	• Water accessibility • Rainfall variability • Temperature variability	• Descriptive statistics • Spearman's correlation • Chi-square test
iv) To assess the adaptation strategies to rainfall and temperature variability in Turkana Central.	• Adaptation strategies ❖ Indigenous strategies ❖ Modern strategies	• Descriptive statistics ❖ Measures of central tendency

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Chapter Summary

This chapter gives details on the study findings, their interpretation, presentation and discussion thereof. The data was analysed using descriptive statistics and statistical tools, including Spearman's correlation and Chi-square test. The inferences made and the discussions were based on the study objectives and research questions. The chapter also describes the characteristics of the respondents in the study area. The results are presented in tables, figures, graphs and charts.

4.2 Household Demographic Characteristics in Turkana Central Sub-County

4.2.1 Respondents' Gender and Age

Sixty-one percent of the household heads interviewed were male, whereas female respondents were represented by 39 % (Table 4.1). However, projections based on 2009 KNBS census results indicated that in 2015 there would be more females than males in Turkana Central; estimated population for females was 100,174 and that for males was 97,595 (GOK, 2013). Owing to the nature of the parameter under study, climate variability, it was essential that respondents were relatively aged. Hence, the minimum age of the respondents was 40 years. Forty-six percent of the respondents were aged between 40-50 years. A similar percentage represented those aged between 51-61 years, while those aged between 62-72 years constituted 5 % of the household heads interviewed. Only 3 % represented respondents aged between 73-83 years. These findings are in line with the findings of a report published by KNBS and SID in 2013 which indicates that Turkana Central residents aged 65 and above years comprised a proportion of 0.03 % of the total population (Ngugi *et al*., 2013). It was also observed that the maximum age of respondents was 83 years. The mean age of the household heads interviewed was 52 years.

4.2.2 Education Level of the Heads of Households

Among the household heads interviewed, 92 % of them had no formal education. Only 8 % of the respondents had achieved primary education. According to Ngugi *et al*. (2013), only 26% of residents in Turkana Central Constituency had a primary level of education. The low literacy levels can be attributed to many causes that inhibit the provision of proper education:

extreme poverty, drought, inter-boundary conflicts, understaffing in schools and cultural practices such as early marriages (GOK, 2013).

Table 4.1: Distribution of Households' Demographic Characteristics in Turkana Central

Demographic Characteristics	**Frequency**	**Percentage**	
Gender			
Male	61	61	
Female	39	39	
Total	100	100	
Age			
40-50 years	46	46	
51-61 years	46	46	
62-72 years	5	5	
73-83 years	3	3	
Total	100	100	
Education level			
None	92	92	
Primary	8	8	
Total	100	100	
Household Size			
0-6 members	41	41	
7-13 members	45	45	
14-20 members	7	7	
Unknown	7	7	
Total	100	100	
Household Income			
Significant Income Source			
Livestock keeping	94	94	
Charcoal selling	1	1	
Crop farming	4	4	
Employment	1	1	
Total	100	100	
Annual Income from Livestock Keeping			
None	4	4	
1,000-50,000 shillings	40	40	
51,000-100,000 shillings	42	42	
101,000-150,000 shillings	7	7	
351,000-400,000 shillings	3	3	
451,000-500,000 shillings	1	1	
501,000-550,000 shillings	3	3	
Total	100	100	
Variables	**Minimum**	**Maximum**	**Mean**
Age of the respondent	40	83	52
Household size	2	20	7
Household annual income from livestock keeping	0	550,000	82,480

Source: Author's field survey, 2014.

4.2.3 Household Size

A distribution of respondents according to the number of members within their households by categories is given in Table 4.1. Forty-six percent of the respondents had 7-13 members, while 41 % of the household heads had a maximum of 6 members. Households with 14-20 members constituted 7 %, with the rest of the respondents declining to disclose their family sizes. In a study of the entire Turkana County, it was established that 64% of households interviewed had more than five members (Opiyo, 2014). In essence, populations of the older settlements in Northern Kenya have grown beyond the capacity of their infrastructure to support them, with population growth rates generally higher in towns than in the rangelands (GOK, 2011). The relatively high number of household members can be attributed to the fact that the traditional Turkana community is polygamous.

4.2.4 Household Income

Given that Turkana Central is predominantly a rangeland, it was expected that most of the residents relied on livestock husbandry as their significant source of livelihood. In correspondence, ninety-four percent of the respondents stated that livestock keeping was the major source of income for their households. Four percent of the household heads, especially those residing at Kang'agetei Village along River Turkwel, cited crop farming as their core source of income. Only 1 % of the respondents stated charcoal selling as their major livelihood. A similar proportion depended majorly on salaried employment. In corroboration, a study conducted in Turkana and Marsabit Counties indicated that majority of household members were unemployed, with only 1.7 % of the respondents in Turkana Central in formal employment (Kaijage & Nyagah, 2009).

A combined proportion of 7 % of the respondents earned 351-550,000 shillings, while 7 % earned 101,000-150,000 shillings and 42 % earned 51,000-100,000 shillings from livestock keeping per year (Table 4.1). Forty percent of the household heads interviewed earned 1,000-50,000 shillings, with 4 % earning nothing from livestock keeping per year. Cash income from livestock keeping in pastoral livelihoods is used to pay for cereals, education, health care and other services (Opiyo, 2014). Considering the fact that pastoralism is traditionally the mainstay of the Turkana, these earnings are meagre, especially for the large families. Kaijage and Nyagah (2009) confirm that annual household incomes for communities living around Lake Turkana are low and irregular; majority of the households earned 50,000 shillings or less per year. Actually, Turkana County registered the highest poverty rate in Kenya, of 90 % (World Bank, 2011).

4.3 Livestock Husbandry in Turkana Central Sub-County

The study findings indicated that the dominant species of livestock reared were goats and sheep. Goats and sheep breed rapidly, as their gestation period is short, hence they recover very fast after droughts (Ouma *et al*., 2012), which are common in Turkana Central. Thirty-six percent of the respondents reared both goats and sheep, 16 % reared only goats, 6 % reared only sheep and 1 % reared only camels. The rest of the respondents kept a varied combination of the different types of livestock as shown in Table 4.2. Ninety-three percent of the respondents had reared the same type of livestock over time; 7% of the respondents had made changes from rearing cattle and sheep to goats and camels.

Table 4.2: Types of livestock reared in Turkana Central Sub-County

Types of livestock	Frequency	Percentage
Cattle, goats, sheep, camels & donkeys	14	14
Goats, sheep, camels & donkeys	2	2
Cattle, goats, camels & donkeys	1	1
Cattle, goats, sheep & donkeys	2	2
Cattle, goats, sheep & camels	11	11
Goats, sheep & donkeys	7	7
Goats, sheep & camels	1	1
Cattle, goats & sheep	2	2
Cattle & goats	1	1
Goats & sheep	36	36
Goats	16	16
Sheep	6	6
Camels	1	1
Total	100	100

Source: Author's field survey, 2014.

The changes in types of livestock reared can be attributed to the fact that cattle are less resistant to dehydration (Badege, *et al*., 2013), yet the study area is hot. In addition, cattle and sheep are more sensitive to droughts than other livestock species; goats, donkeys and camels are more resistant to drought induced stresses (Ouma *et al*., 2012). The camels, for example, can browse over tall shrubs and are, thus, adaptive to such ASAL environments (ILRI, 2006). Plates 4.1, 4.2 and 4.3 show some of the livestock species reared in the study area.

Plate 4.1: Camels browsing on shrubs in Nabuin Village, Kapua Location, Turkana Central
Source: Author's field survey, 5th December 2014.

Plate 4.2: Goats and sheep grazing in Kapua Location, Turkana Central Sub-County
Source: Author's field survey, 5th December 2014.

Plate 4.3: Donkeys grazing in Kapua Location, Turkana Central Sub-County
Source: Author's field survey, 5th December 2014.

According to Oduor *et al*. (2012), vegetation in Turkana Central consists of shrub savannah, trees, thickets and herbaceous vegetation; evergreen and semideciduous woodlands are found along Turkwel and Kerio Rivers. Shrubs and tree leaves were the two most important pastures for the pastoralists' livestock, as stated by 66 % and 32 % of the respondents, respectively. Some of these tree and shrub species are listed in Table 4.3; *Acacia tortilis* being the most abundant tree species. Plate 4.4 shows some of these significant pastures in Kapua Location. Only 2 % of the household heads interviewed cited grass as the primary forage for their livestock. The grass species within the study area are *Setaria sphacelata, Eragrostis racemosa, Becium obovatum, Chloris virgata, Eriochloa fatmensis, Barleria acanthoide* and, *Panicum sporobolus* (Oduor *et al*., 2012).

Eighty-six percent of the respondents depended mostly on both permanent and seasonal rivers for water for their livestock, while 12 % depended on wells and boreholes. The dominant source of water was River Turkwel (Plate 4.5). Lake Turkana, formerly named "Lake Rudolf" in 1988 and commonly known as the Jade Sea due to its remarkable greenish colour caused by algae (Avery, 2012), was cited as a source of water for livestock grazing along its shores. Two percent of the respondents obtained water primarily from laggas for their animals. These results are summarized in Table 4.4. The study also established that during rainy seasons, pastoralists water their animals in natural ponds, referred to as "*egoch*" in the Turkana language. Large ponds take long to dry up after the rainy seasons end. Thus, pastoralists herding livestock away from the major rivers water their animals in these ponds during the onset of the dry seasons.

Table 4.3: Pasture tree and shrub species in Turkana Central Sub-County

Turkana Name	**Scientific Name**	**Common English/Swahili Name**
Ewoi/Etir	*Acacia tortilis*	Umbrella thorn
Esanyanait	*Acacia elatior*	River acacia
Edurukoit	*Acacia albida*	Apple-ring acacia
Ekunoit	*Acacia senegal*	Gum arabic
Ebei	*Balanites orbicularis*	Mbamba ngoma
Elamach	*Balanites pedicellaris*	Small green thorn
Eroronyit	*Balanites aegyptiaca*	Desert date
Epat	*Grewia bicolor*	False brandy bush
Engomo	*Grewia tenax*	White cross-berry
Ekalale	*Zizyphus mauritiana*	Jujube
Ereng	*Cadaba farinosa*	Herd's boy fruit
Ekurichanait	*Delonix elata*	Creamy peacock flower
Esekon	*Salvadora persica*	Toothbrush tree
Edapal	*Dobera glabra*	Mkupa
Erdung	*Boscia coriacea*	Shepherd’s tree
Echoke	*Ficus sycomorus*	Sycamore fig
Esajait	*Lawsonia inermis*	Henna tree
Edome	*Cordia sinensis*	Grey-leaved saucer berry
Epeduru	*Tamarindus indica*	Tamarind
Emeyan	*Berchemia discolor*	Brown ivory/Wild almond
Eterai	*Prosopis chilensis*	Chilean mesquite
Eterai	*Prosopis juliflora*	Mexican thorn

Source: Oduor *et al*. (2012); Author’s field survey, 2014.

Table 4.4: Significant pastures and water sources in Turkana Central Sub-County

Natural Resources	Frequency	Percentage
Pasture types		
Shrubs	66	66
Tree leaves	32	32
Grass	2	2
Total	100	100
Water sources		
Rivers	86	86
Wells/boreholes	12	12
Laggas	2	2
Total	100	100

Source: Author's field survey, 2014.

Plate 4.4: Acacia trees and shrubs in Kapua Location, Turkana Central Sub-County

Source: Author's field survey, 5th December 2014.

Plate 4.5: River Turkwel, the dominant water source, traversing Kang'atotha Location in Turkana Central Sub-County

Source: Author's field survey, 2014.

4.4 Rainfall and Temperature Variability in Turkana Central Sub-County

4.4.1 Rainfall Variability

With climate variability and change experienced in East Africa, the rainfall patterns are no longer predictable regarding timing and levels (Ute *et al.*, 2012). The amount of rainfall received in Turkana Central varied annually, displaying a general trend of 160.7 mm increase over the thirty-two years, calculated basing on the trend line's equation (y = 5.0208x + 109.73) in Figure 4.1. To substantiate the fact that rainfall amount received increased, the mean rainfall for Turkana Central was 159.8 mm from 1983-1998, while in the consecutive 16 years the mean was 225.4 mm. In general, the mean rainfall over the thirty-two years was 192.6 mm. The lowest annual rainfall, 38.9 mm, was recorded in the year 2000, while the highest value recorded in the year 2012 was 421.4 mm, giving a range of 382.5 mm. Rainfall amounts had always peaked from the month of March to May (Figure 4.2). However, over the last 10 years rainfall became bimodal, with another peak in November. Generally, low rainfall amounts were received in the months of February and June over the 32 years.

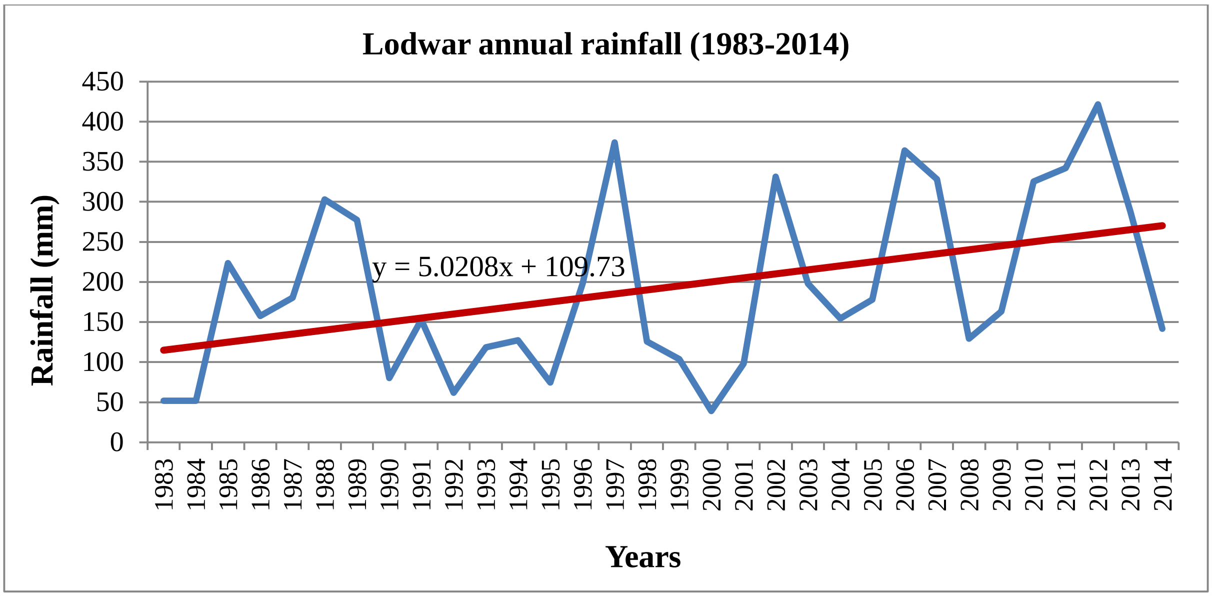


Figure 4.1: Graph showing annual rainfall totals for 1983-2014 for Lodwar, Turkana Central

Source: Lodwar Meteorological Department, Turkana Central Sub-County, 2015.

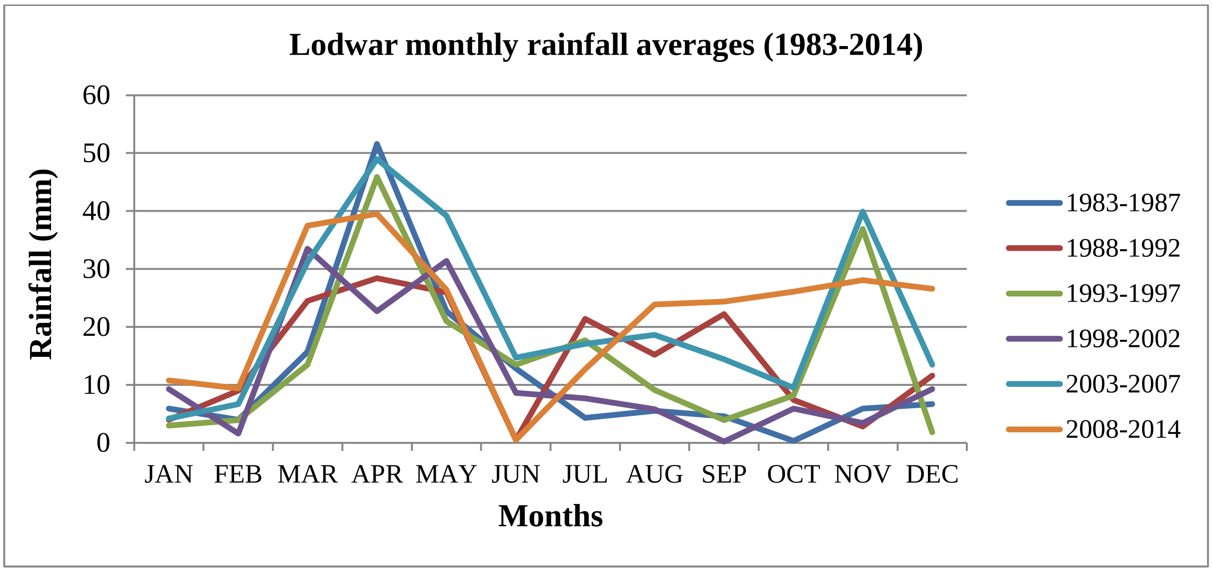


Figure 4.2: Graphs showing monthly rainfall averages for 1983-2014 for Lodwar, Turkana Central Sub-County

Source: Lodwar Meteorological Department, Turkana Central Sub-County, 2015.

On the contrary, only 8 % of the respondents interviewed concurred that rainfall amount received in Turkana Central over the last 30 years had increased. Forty percent of the respondents stated that there had been no change, with 52 % of the respondents citing that the amount of rains had decreased (Figure 4.3).

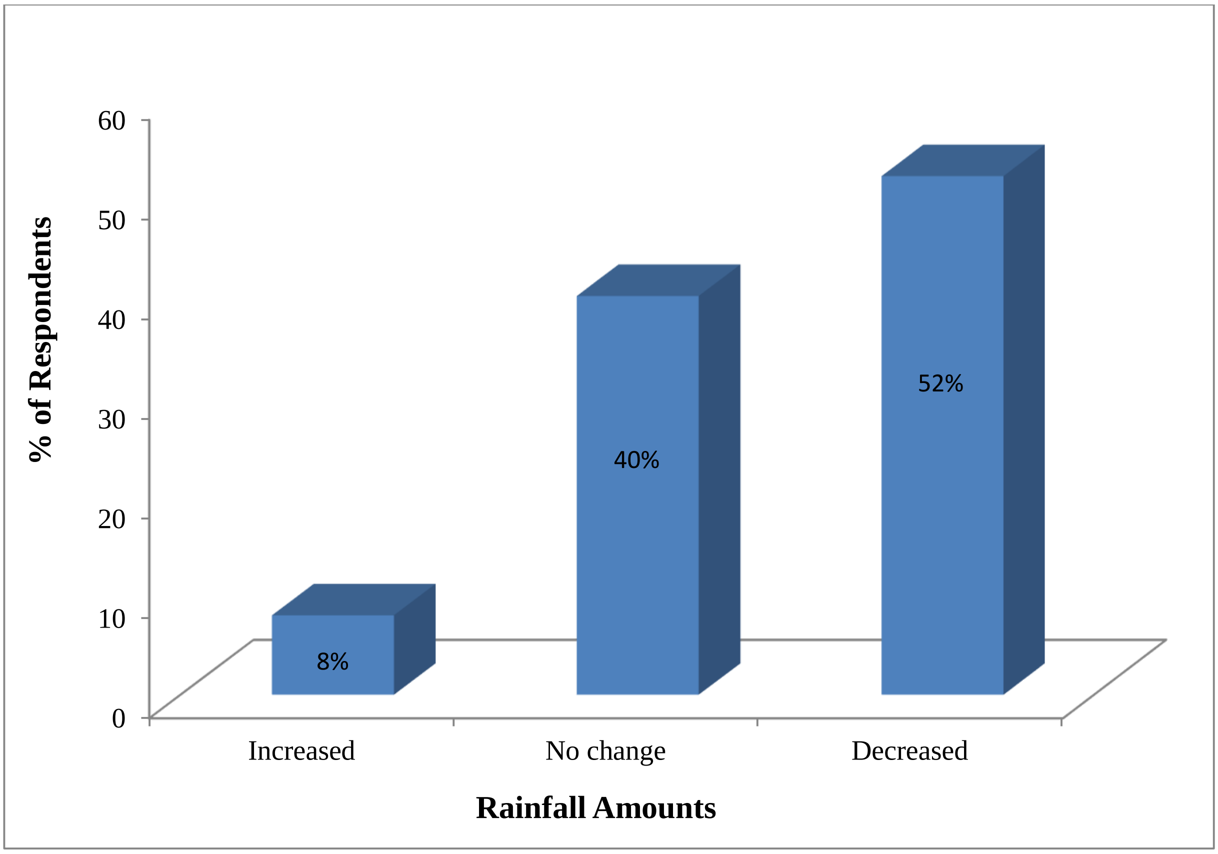


Figure 4.3: Respondents' perception on rainfall variability in Turkana Central

Source: Author's field survey, 2014.

The difference in perception about changes in rainfall by respondents necessitated collecting more data. Considering that 54 % of the respondents were more than 50 years, they could have viewed rainfall changes on a longer term basis than the 30 years. Thus, analysis of rainfall data for 55 years, 1960-2014, was undertaken; including data for 1960-1982 documented by Avery (2010). The plotted graph displayed a decrease of 14.8 mm, calculated basing on the trend line's equation in Figure 4.4. The average rainfall received during the 55 years was 209.8 mm. More rainfall was received between 1960-1977 than in the subsequent years, evidenced by a mean of 248.6 mm and three peaks of rainfall amounts higher than 472 mm. Thereafter, there was a marked decrease in rainfall amounts from 1978 to 1995, with a mean of 153.4 mm; way below the mean rainfall for the 55 years. Though rainfall amounts increased during the period 1996-2014, to a mean of 226.5 mm, it never exceeded 422 mm at any one year.

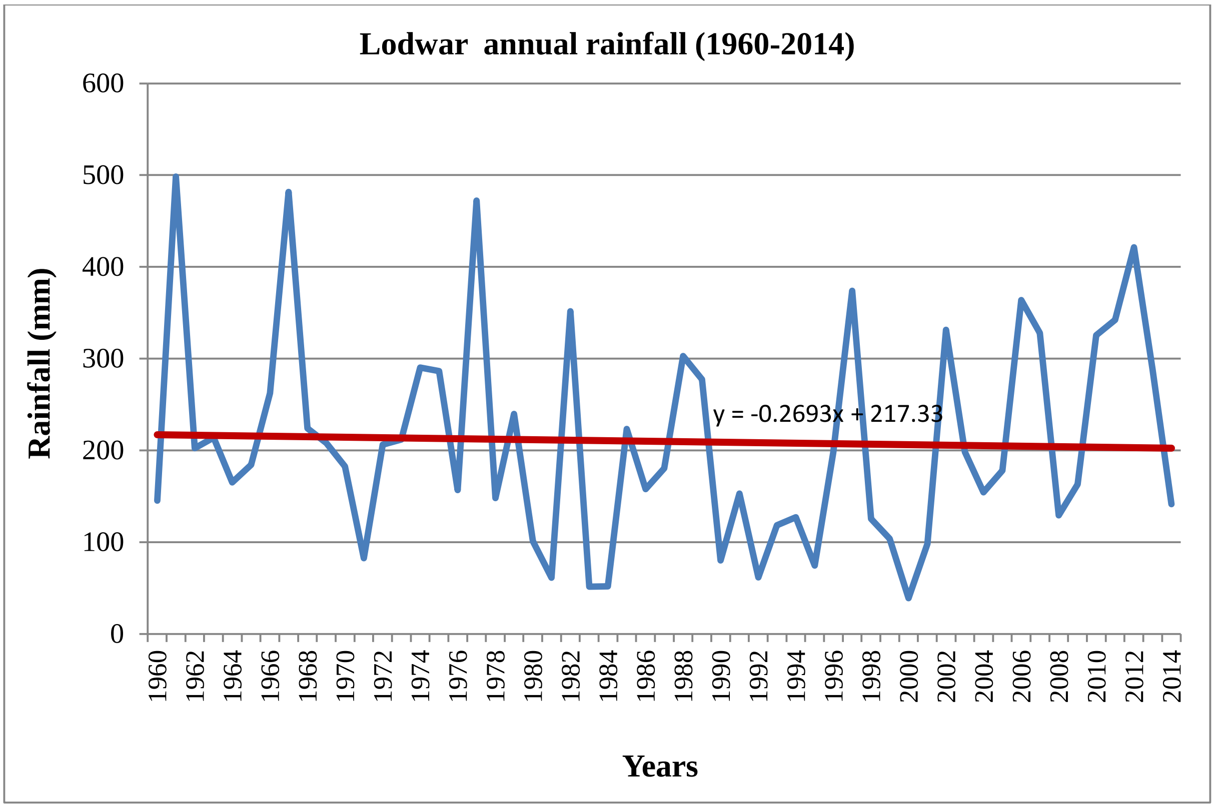


Figure 4.4: Graph showing annual rainfall totals for 1960-2014 for Lodwar, Turkana Central

Source: Kenya Meteorological Department, Nairobi and Lodwar, 2015.

Fifty-one percent of the respondents agreed that incidences of floods had increased during the rainy seasons over the last three decades; 44 % stating March and April as the months when flooding occurred, and 7 % stating November and December. According to 49 % of the respondents, incidences of floods remained the same over the thirty years (Figure 4.5). The Turkana elders at a focus group discussion at Kapua location told of a severe flood called "Ngikaala ka Akwanyang", meaning the floods swept away all the camels owned by Mr. Akwanyang. Turkana Central Ministry of Agriculture personnel stated that severe floods were experienced in the region during the 1997 El Niño, in 2006, 2007, 2010, 2011 and 2012. According to data obtained from Lodwar Meteorological Department, all the six years registered high annual rainfall amounts of more than 325 mm.

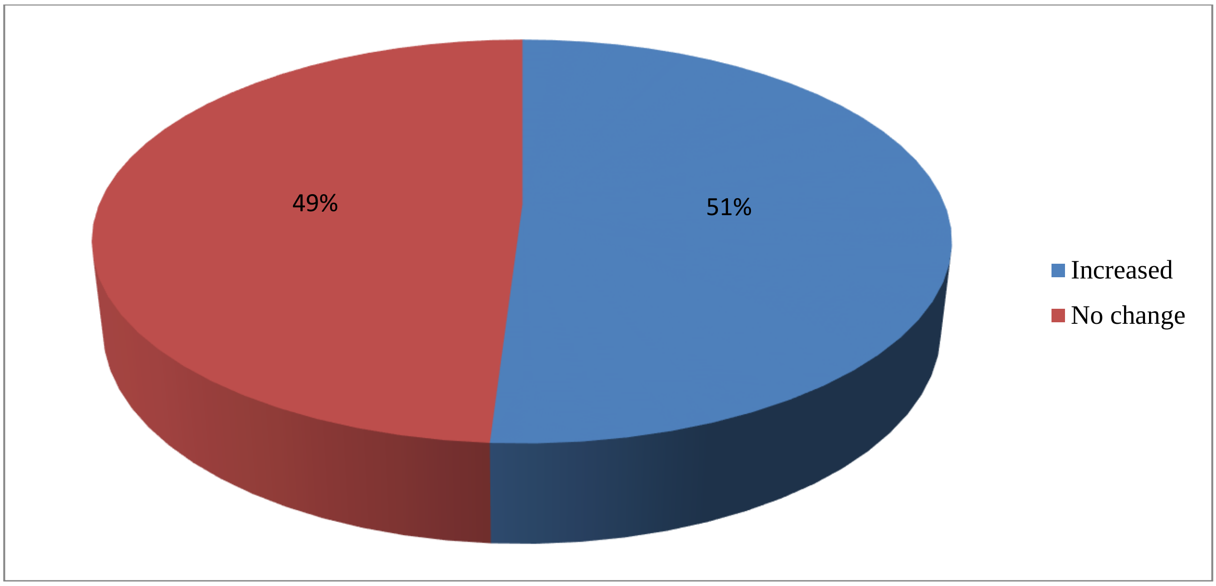


Figure 4.5: Respondents' perception on frequency of floods in Turkana Central Sub-County

Source: Author's field survey, 2014.

According to 82 % of the respondents, droughts had become more prolonged over the last 30 years in Turkana Central Sub-County, persisting for three to five months unlike the previous two months. On the other hand, 18 % of the household heads interviewed felt that there had been no change in the duration of the drought season (Figure 4.6). In a focus group discussion held at Kapua Location, the elders recalled a severe drought in 1960 called "Namotor", where livestock hides were consumed as food. Ministry of Agriculture and Livestock Department personnel told of severe droughts experienced in Turkana in the years 1983/1984 (*Nakwajom*), 2000 (*Kichutanak*) and 2004/2005 (*Kanyang'ang'iro*). Ebei *et al.* (2007) tabulated data on drought occurrence in the then Turkana District, now Turkana County (Table 4.5).

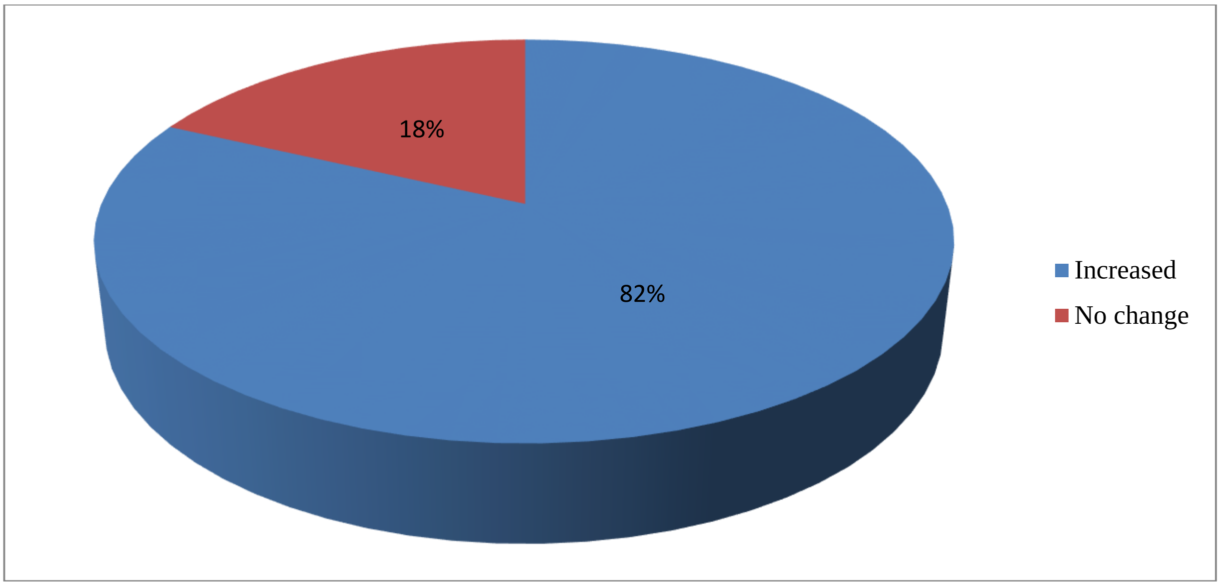


Figure 4.6: Respondents' perception on drought duration in Turkana Central

Source: Author's Field survey, 2014.

Table 4.5: Drought events in Turkana County

Turkana name for different drought periods	**Year**
Lotiira	1952
Namotor	1960
Kimududu/Kibekbek	1970
Kiyoto atang'aa/Lopiar	1980
Lokwakoyo/Alkalkal	1990
Logara/Epompo	2000

Source: Ebei, Oba and Atuja (2007).

4.4.2 Temperature Variability

Kenya has experienced generally increasing temperature trends, with an annual rate of 0.2°C over the past five decades (IOM, 2010). Changes monitored by Kenya Meteorological Department indicate higher rises in temperature in Northern parts of the country as compared to other parts (Ute *et al.*, 2012). Typical of the tropical region within the Horn of Africa, Turkana County experiences high temperatures throughout the year, displaying a minimum of 24°C, a maximum of 38°C and a mean of 30°C (Kaijage & Nyagah, 2009; Opiyo, 2014).

Temperatures experienced in Turkana Central varied annually, displaying a general trend of 0.4°C increase over the thirty-two years, calculated basing on the trend line's equation ($y = 0.013x + 29.569$) on Figure 4.7. In agreement with the fact that temperatures had increased, the mean temperature from 1983-1998 was 29.7°C while the mean was 29.9 ºC from 1999-2014. The mean temperature over the 32 years was 29.8°C. The lowest average temperature, 29.2°C, was recorded in the year 1985, while the highest temperature (30.3°C) was recorded in 2009; giving a range of 1.1°C. Generally, high temperatures were experienced in March (30.6°C) and in October (30.7°C), with relatively lower temperatures (29°C) experienced in July and December over the entire period (Figure 4.8). Temperatures experienced during the months of April to September were notably higher for the period 2008-2014 than the previous years (Figure 4.8). These inferences were made with 92 % of data, as some data - notably minimum temperature data for 1983 and 1986 - was missing.

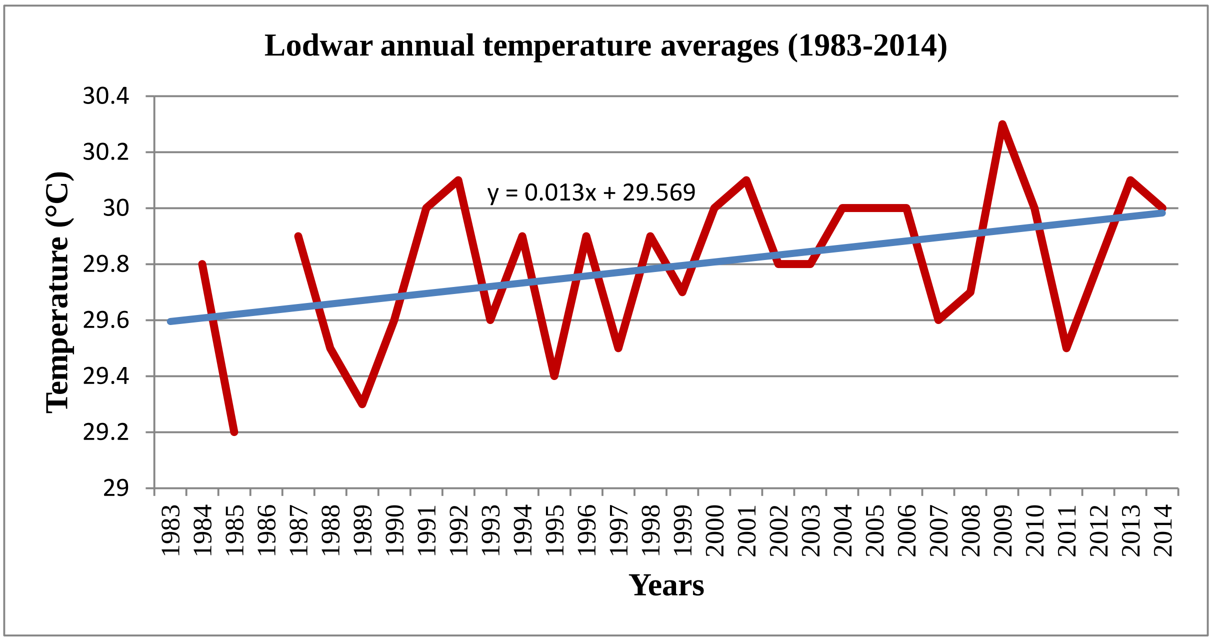


Figure 4.7: Graph showing annual temperature averages for 1983-2014 for Lodwar, Turkana Central Sub-County

Source: Kenya Meteorological Department, Lodwar and Nairobi, 2015.

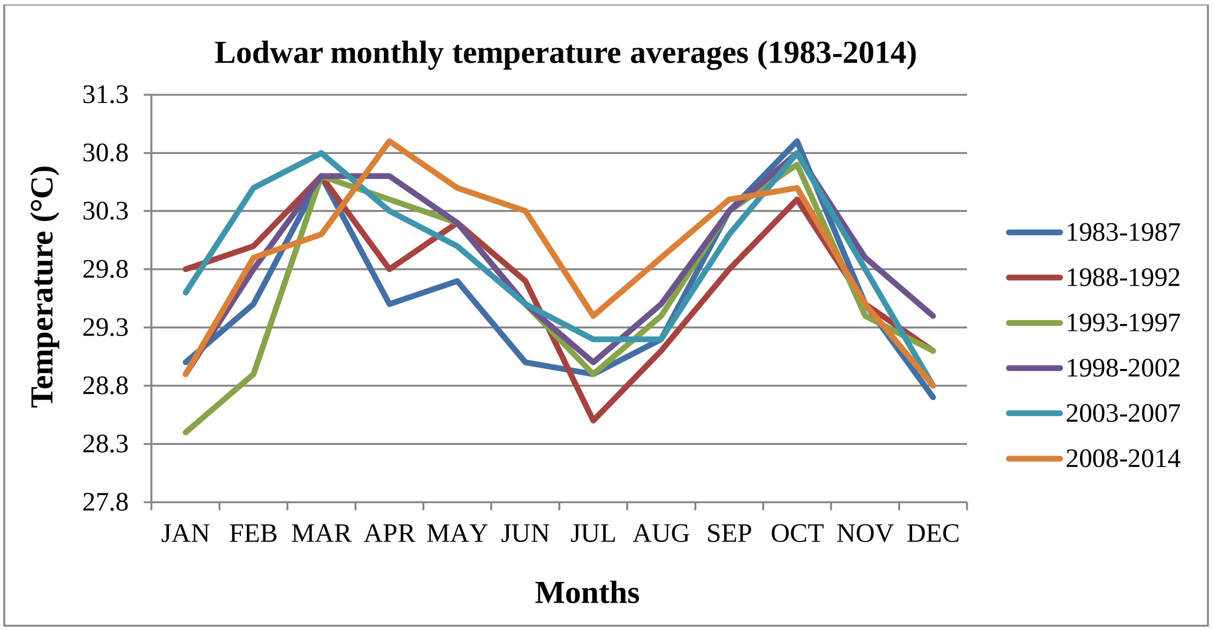


Figure 4.8: Graphs showing monthly temperature averages for 1983-2014 for Lodwar, Turkana Central

Source: Kenya Meteorological Department, Lodwar and Nairobi, 2015.

An analysis of the annual mean maximum and minimum temperatures revealed that maximum temperatures increased more than minimum temperatures. In essence, there was a greater increase in day temperatures than in night temperatures. Annual mean maximum temperatures displayed a trend of 0.45°C increase over the thirty-two years, calculated based on the trend line's equation ($y = 0.0141x + 35.221$) on Figure 4.9. In comparison, annual mean minimum temperatures displayed a trend of 0.35°C increase over the thirty-two years, calculated based on the trend line's equation ($y = 0.0108x + 23.928$) on Figure 4.10. An average of the two increases gives a general increase of 0.4°C, equivalent to the increase computed based on the trend line's equation on Figure 4.7. The mean maximum and minimum temperatures over the 32 years were 35.5°C and 24.1°C, respectively; hence the general average of 29.8°C. Of significance to note is that from the year 1998, annual mean maximum temperatures were at least 35.4°C.

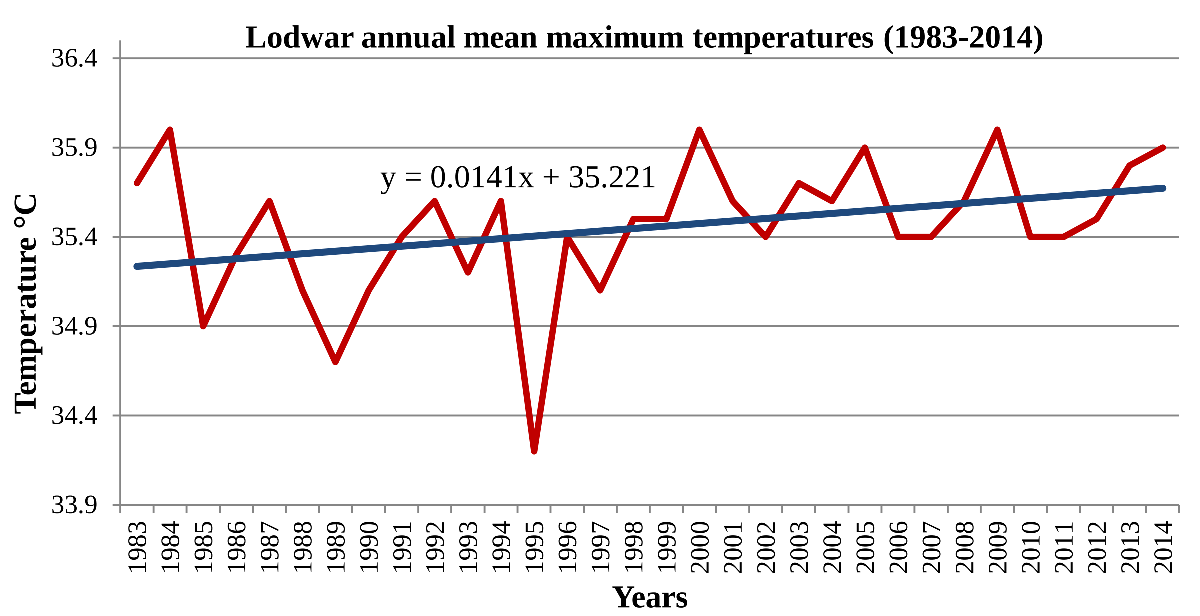


Figure 4.9: Graphs showing annual mean maximum temperatures for 1983-2014 for Lodwar, Turkana Central Sub-County

Source: Kenya Meteorological Department, Lodwar and Nairobi, 2015.

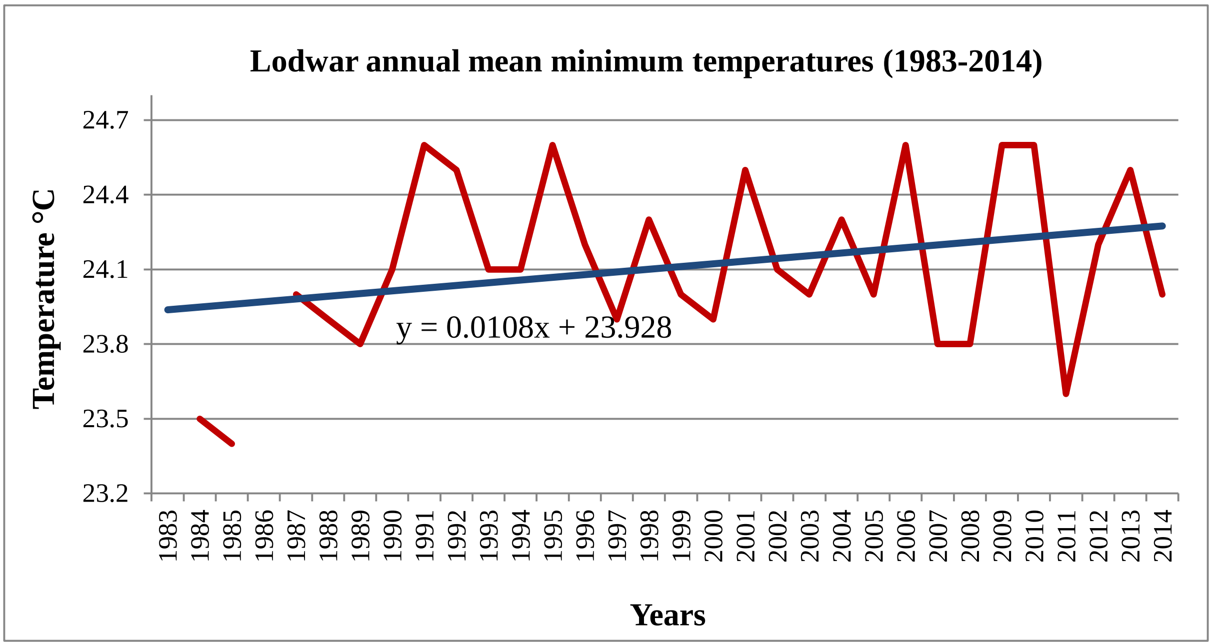


Figure 4.10: Graphs showing annual mean minimum temperatures for 1983-2014 for Lodwar, Turkana Central Sub-County

Source: Kenya Meteorological Department, Lodwar and Nairobi, 2015.

In concurrence, according to 88 % of the respondents, temperatures over the last 30 years had increased. Ten percent of the household heads stated that there had been no change, with only 2 % citing that temperatures had decreased (Figure 4.11). In a similar study in arid and semi-arid Matopo District in Zimbabwe, 90 % of the respondents pointed out that temperatures had increased during the period 1970 to 2008 (Dube & Phiri, 2013). Data from Zimbabwe Meteorological Services Department corroborated this; temperature increase of about 1.12 °C was registered in that span of 40 years (ibid).

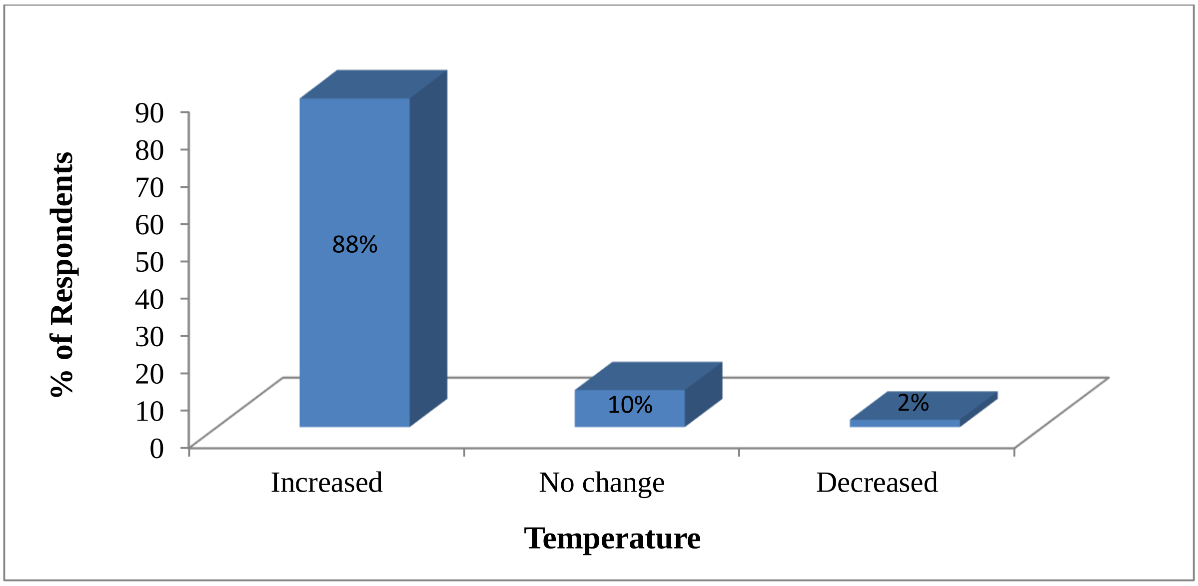


Figure 4.11: Respondents' perception on temperature variability in Turkana Central

Source: Author's field survey, 2014.

4.5 Pasture Availability and Water Accessibility in Turkana Central Sub-County

4.5.1 Pasture Availability

Pasture, forests and medicinal plants are critical resources upon which people in Northern Kenya and other dry areas in the country depend, with women and youth playing key roles in natural resource management though older men have control over most resources (GOK, 2011). The natural pasture of the arid and semi-arid rangelands gives the region a comparative advantage in livestock production (ibid). Notwithstanding, according to 74 % of the respondents, pasture availability in Turkana Central had decreased over the last 30 years, whereas 8 % of the respondents stated the contrary. Respondents represented by 18 % felt that there had been no change in availability of pastures in the three decades (Figure 4.12). The invasive *Prosopis juliflora* has overwhelmed the region's grasslands by shutting out other species through interlinking canopies; it has displaced indigenous species from the banks of River Turkwel (Avery, 2012). Yet, according to Turkana Central Ministry of Agriculture officers, the leaves of the tree are very bitter and its pods too sugary; ideally, the species is not fit for livestock consumption. Nonetheless, livestock fed on this species.

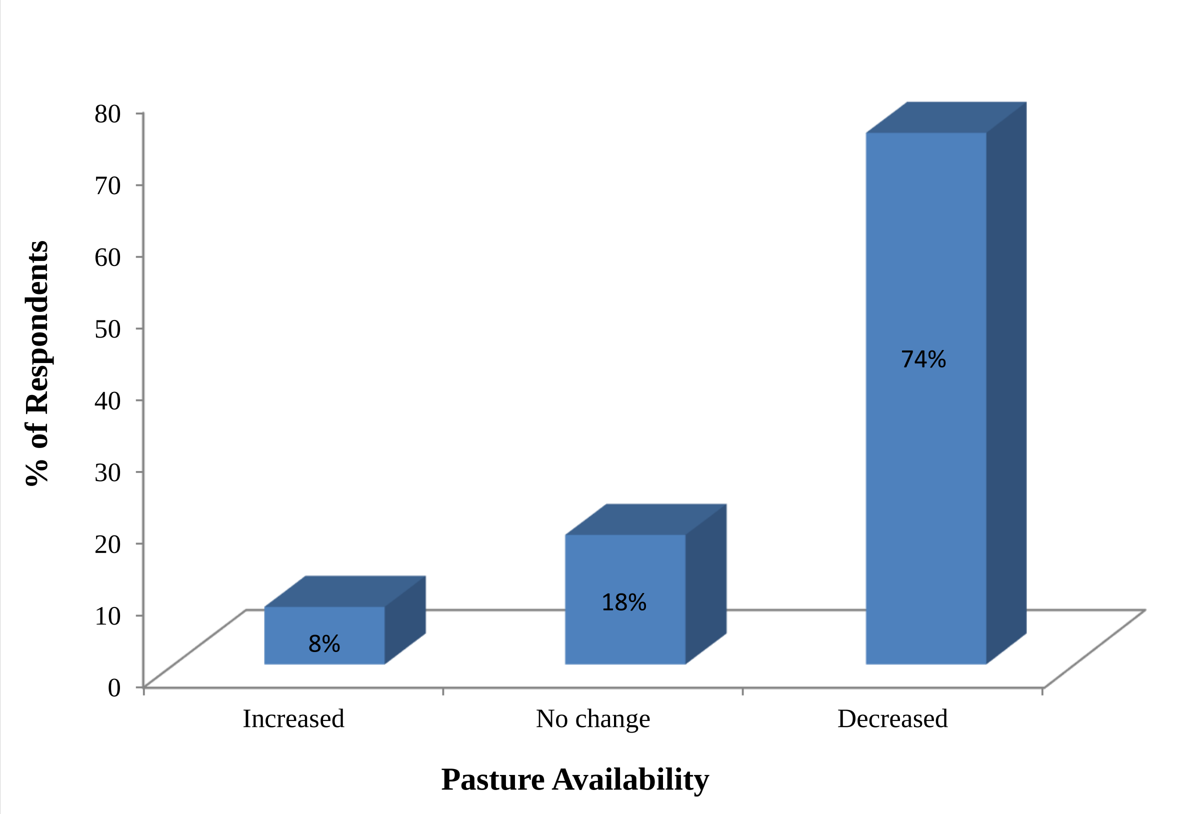


Figure 4.12: Respondents' perception on pasture availability in Turkana Central

Source: Author's field survey, 2014.

The distance covered by pastoralists in search of pastures during the rainy seasons was relatively the same over the three decades; majority of the respondents covered 2-3 km as illustrated in Table 4.6 and Table 4.7. During the wet seasons, grass and shrubs sprouted on the banks of perennial and seasonal rivers and around areas where water accumulated in natural depressions and ponds. Similar to the scenario along Turkwel, Kerio and Kauwalathe Rivers, seasonal floods inundate pastures adjoining River Omo in Ethiopia, thus sustaining both livestock and wildlife populations (Avery, 2013).

Table 4.6: Distance to livestock grazing area during rainy season 30 years ago

Distance	Frequency	Percentage
0-1 km	27	27
2-3 km	59	59
4-5 km	7	7
6-7 km	5	5
8-9 km	2	2
Total	100	100

Source: Author's field survey, 2014.

Table 4.7: Distance to livestock grazing area during rainy season during the study period

Distance	Frequency	Percentage
0-1 km	19	19
2-3 km	55	55
4-5 km	17	17
6-7 km	5	5
8-9 km	4	4
Total	100	100

Source: Author's field survey, 2014.

However, the scenario was different during droughts. Thirty years ago, 74 % of the respondents trekked for 10-19 km; while during the study period, 66 % of the respondents trekked for 15-24 km to access pastures for their livestock. In the recent years, pastoralists had to move further in search of pastures. These results are shown in Table 4.8 and Table 4.9. There has been an increased shortage in pasture in Turkana County due to severe droughts (Watson & Binsbergen, 2008). With dwindling fodder resources, most pastoral households are forced to migrate far and wide or trek long distances (Okoti *et al.*, 2014). Plate 4.6 shows the pasture situation during the dry season in August, 2014: most shrubs and trees shed their leaves to reduce water loss during transpiration through stomata, and grass dried up.

Table 4.8: Distance to livestock grazing area during droughts 30 years ago

Distance	Frequency	Percentage
0-4 km	1	1
5-9 km	10	10
10-14 km	43	43
15-19 km	31	31
20-24 km	15	15
Total	100	100

Source: Author's field survey, 2014.

Table 4.9: Distance to livestock grazing area during droughts during the study period

Distance	Frequency	Percentage
5-9 km	7	7
10-14 km	27	27
15-19 km	35	35
20-24 km	31	31
Total	100	100

Source: Field survey, 2014.

Plate 4.6: Sparsely-vegetated pasture land during dry season in Kapua Location, Turkana Central Sub-County

Source: Field survey, 14^{th} August 2014.

However, computed Normalized Difference Vegetation Index (NDVI) values for three Landsat images of the study area revealed a different scenario from that which the pastoralists depicted. According to the values, the level of greenness in Turkana Central Sub-County had increased over the years. Very low values of NDVI (0.1 and below) correspond to barren areas of rock, sand or snow; moderate positive values, approximately 0.2 to 0.4, represent shrub and grassland, while values approaching 1 indicate temperate and tropical rainforests (Weier & Herring, 2000). Thus, means for NDVI values representing vegetation were computed. In the year 1984 and 2002, the mean NDVI values were 0.262 and 0.278, respectively, which correspond to gradually increasing shrub and grassland vegetation over the period. The mean NDVI value computed for the year 2014, 0.377, indicates denser shrub and grassland vegetation than that in the former two years. Figures below give a clear pictorial illustration of the changes in vegetation in Turkana Central over the years.

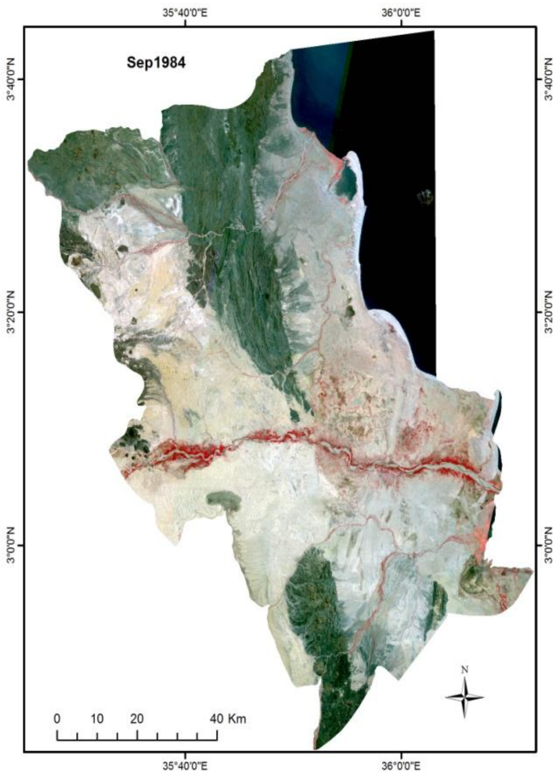


Figure 4.13: Landsat image for Turkana Central Sub-County for September, 1984

Source: Regional Centre for Mapping of Resources for Development, Nairobi

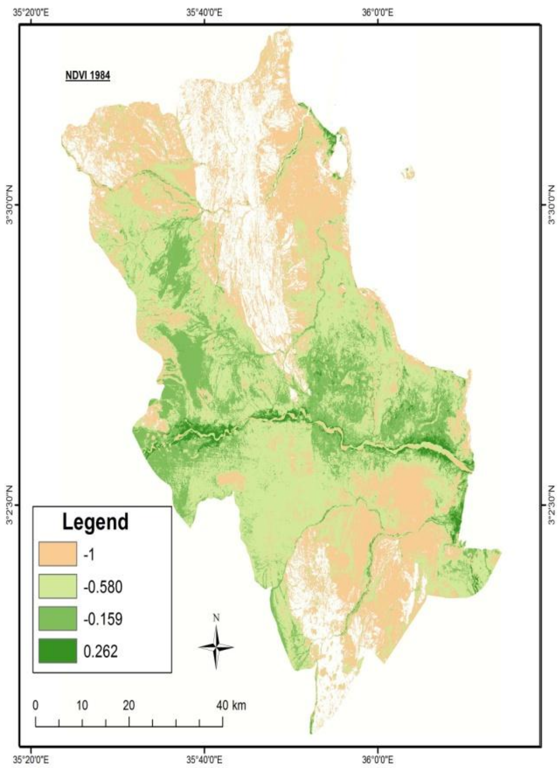
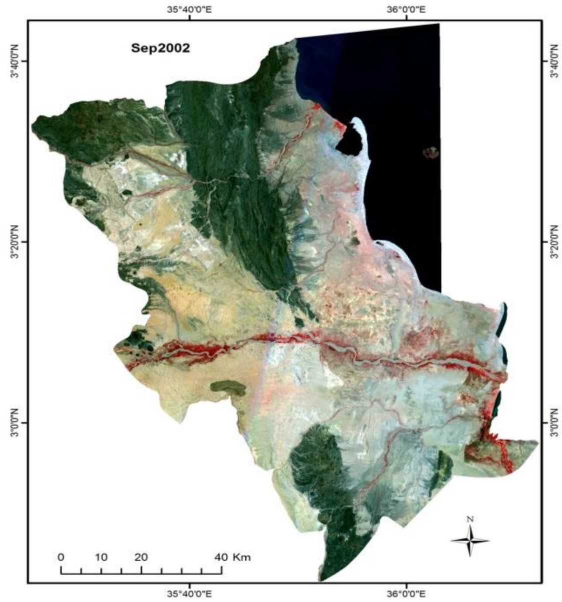


Figure 4.14: NDVI map for Turkana Central Sub-County for September, 1984

Source: Field data, 2015.



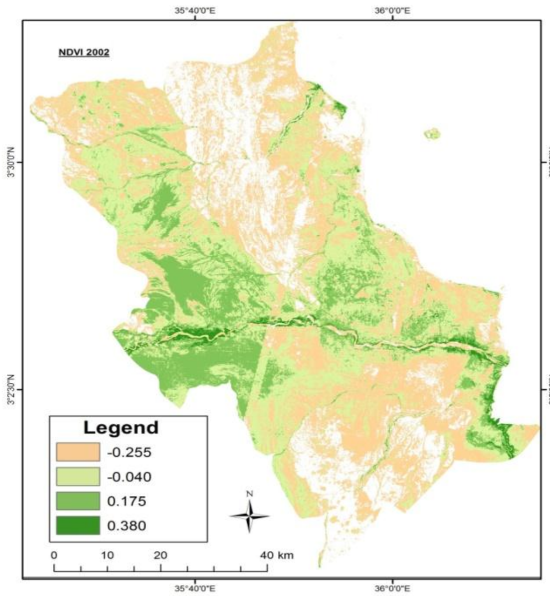
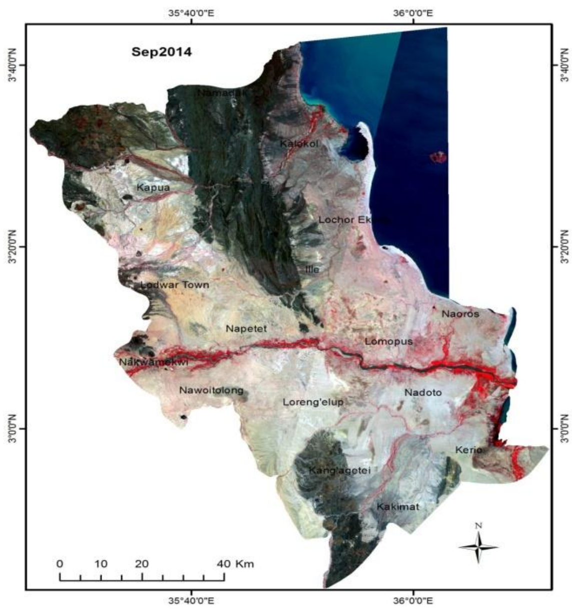


Figure 4.15: Landsat image for Turkana Central Sub-County for September, 2002

Source: Regional Centre for Mapping of Resources for Development, Nairobi

Figure 4.16: NDVI map for Turkana Central Sub-County for September, 2002

Source: Field data, 2015.



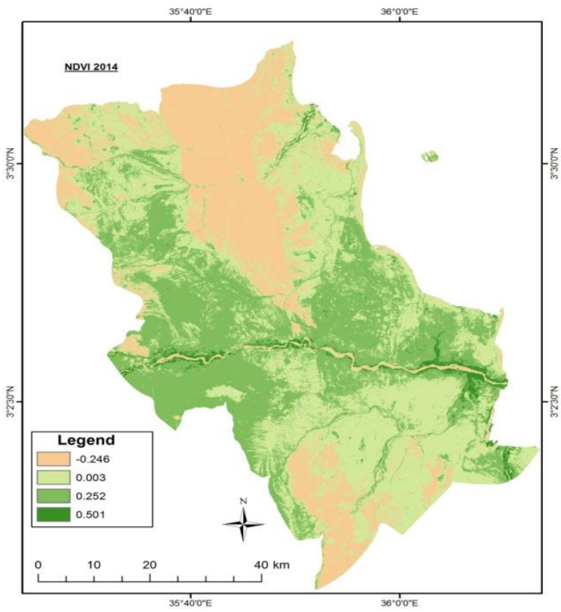


Figure 4.17: Landsat image for Turkana Central Sub-County for September, 2014

Source: Regional Centre for Mapping of Resources for Development, Nairobi

Figure 4.18: NDVI map for Turkana Central Sub-County for September, 2014

Source: Field data, 2015.

In agreement to findings on vegetation changes as per NDVI, it was found out that the surface area under vegetation in Turkana Central Sub-County had increased over the years. The surface area covered by vegetation in 1984 was 613.5 km^2, while in 2002 it was 885.2 km^2 (Table 4.14). In 2014, there was a further increase in area under vegetation to 931.4 km^2. In total, there was of an increase of 317.9 km^2 of land covered by vegetation from the year 1984 to the year 2014. In 1984, most of the vegetation was found along River Turkwel (Figure 4.20); in 2014 there was riparian vegetation along seasonal rivers, vegetation along Lake Turkana shoreline and denser vegetation along Rivers Turkwel and Kerio (Figure 4.22). The increase in vegetation can be partly attributed to the aggressive invasion of the plant species indigenous to Mexico, *Prosopis juliflora,* which was introduced to Lodwar after being introduced to Kenya in the 1980s (Avery, 2012). During the study, it was observed that the banks of both seasonal and perennial rivers, especially Kauwalathe and Turkwel Rivers, had high densities of *Prosopis juliflora* species.

4.5.2 Water Accessibility

Turkana County has multiple water sources: hand-dug wells in dry river beds, shallow wells, water pans, rock catchments, boreholes and rivers, such as Turkwel, Tarach and Kerio Rivers (Oxfam, 2012). In fact, during a Focus Group Discussion, Water Resources Management Authority Lodwar Office confirmed that Turkana Central was found to have a lot of underground water in a reservoir at Napuu. However, according to the Turkana Central Livestock Department personnel, the water had not been exploited; only a pilot pump had been set up. Among the household heads interviewed, 36 % had observed an increase in water accessibility in Turkana Central Sub-County over that last 30 years. Forty-nine percent of the respondents however, had observed a decrease, while 15 % had not observed any change in water accessibility (Figure 4.19).

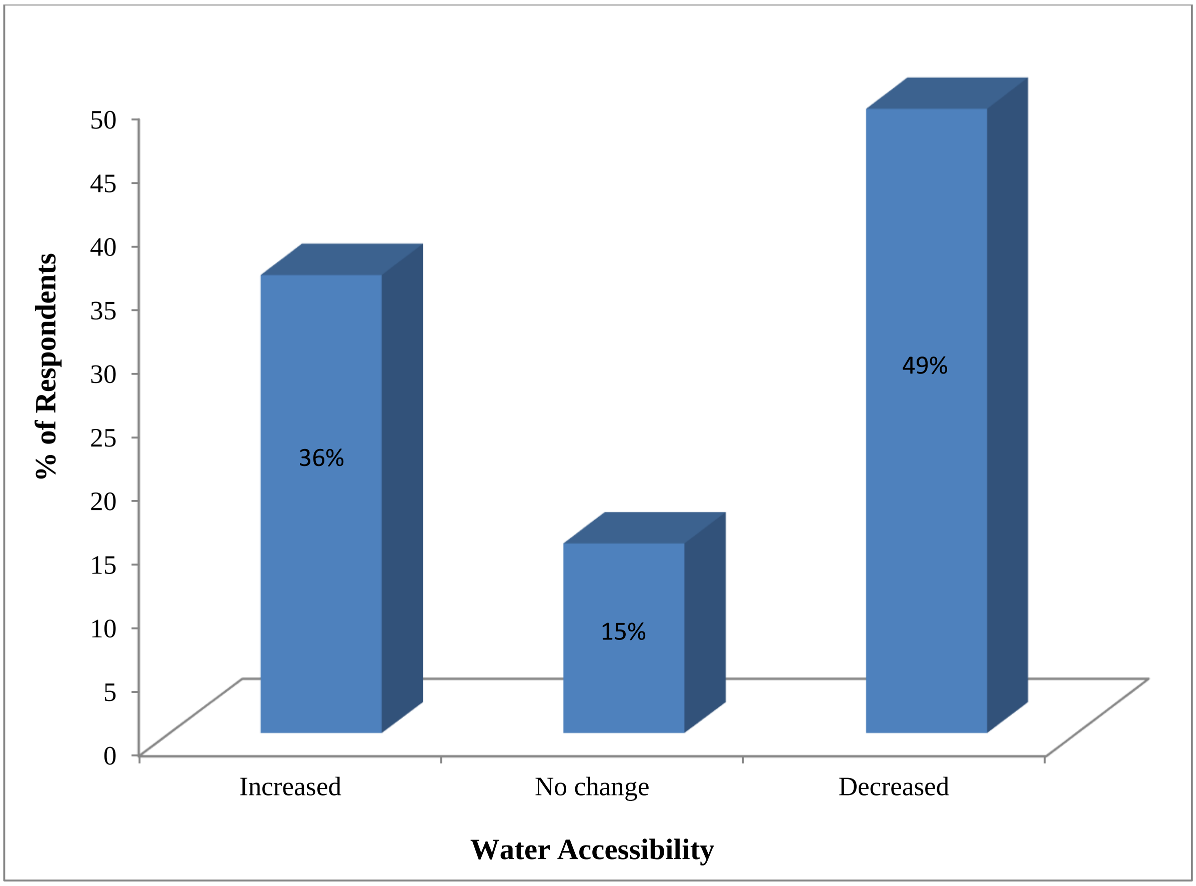


Figure 4.19: Respondents' perception on water accessibility in Turkana Central

Source: Author's field survey, 2014.

Most of the pastoralists interviewed covered relatively the same distance, 251-500 metres, in search of water during the rainy seasons over the last 30 years, as illustrated in Table 4.10 and Table 4.11. Thirty years ago, only 1 % of the household heads had to trek for more than a kilometre to water their livestock. During the study period, 3 % of the respondents had to trek for 1.25-2 km to access watering points for their livestock. The pastoralist attributed the similarity in distance to water sources during the rainy seasons over the three decades to the fact that seasonal rivers and the natural ponds, called "*egoch*", held water then: these water reservoirs were accessible by most pastoralists. Kaijage and Nyagah (2009) also found out that the distance of many communities residing in Northern Marsabit and Central Turkana from water sources during the wet season was not as far as expected, considering that these areas are arid and semi arid, since water sources initially acted as incentives for settlements. For instance, majority of the community members in Marsabit County - at Illeret, Loiyangalani and North Horr - walked for less than one or 1-2 km or an hour or less, to access water sources.

Table 4.10: Distance to livestock water source during rainy seasons 30 years ago

Distance	Frequency	Percentage
1-250 m	25	25
251-500 m	48	48
501-750 m	22	22
751-1000 m	4	4
1501-1750 m	1	1
Total	100	100

Source: Author’s field survey, 2014.

Table 4.11: Distance to livestock water source during rainy seasons during the study period

Distance	Frequency	Percentage
1-250 m	30	30
251-500 m	47	47
501-750 m	18	18
751-1000 m	2	2
1251-1500 m	1	1
1751-2000 m	2	2
Total	100	100

Source: Author’s field survey, 2014.

During droughts more pastoralists had to walk long distances during the study period unlike in the past, in search of water for their livestock, as summarized in Tables 4.12 and 4.13. Of the households interviewed, 56 % trekked for 6-9 km to reach water points during droughts 30 years ago. In the recent past, 61 % of the respondents covered the same distance to access water during droughts. A similar study conducted at Lorengelup, Kang’irisae and Kalokol in Central Turkana affirmed that a significant number of interviewed households had to walk longer distances, for more than 5 km, to water sources (Kaijage & Nyagah, 2009). The pastoralists stated that the more severe and prolonged droughts resulted in most seasonal rivers drying up, necessitating further movement by more herders unlike three decades ago. Plate 4.7 gives an illustration of a dry river bed during the dry season in August, 2014. Given that the region is under Intergovernmental Authority on Development (IGAD) jurisdiction -

Kenya included - is expected to be water-stressed by 2025 (IGAD, 2007), pastoralists in Turkana Central are likely to trek longer distances to reach water points, especially during droughts.

Table 4.12: Distance to livestock water source during droughts 30 years ago

Distance	**Frequency**	**Percentage**
0-1 km	3	3
2-3 km	6	6
4-5 km	35	35
6-7 km	30	30
8-9 km	26	26
Total	100	100

Source: Field survey, 2014.

Table 4.13: Distance to livestock water source during droughts during the study period

Distance	**Frequency**	**Percentage**
2-3 km	8	8
4-5 km	31	31
6-7 km	32	32
8-9 km	29	29
Total	100	100

Source: Field survey, 2014.

Plate 4.7: Dry River Kalotum bed during the dry season in Turkana Central Sub-County

Source: Author's field survey, 2014.

On the contrary, land cover maps designed depicted an increase in water availability (Figures 4.20, 4.21 and 4.22). The surface areas covered by water in 1984 and 2002 were 793.8 km^2 and 811.95 km^2, respectively (Table 4.14). In 2014, this area had further increased to 854.3 km^2, giving a total increase of 60.5 km^2 since the year 1984. This means that there was more water available for the livestock in 2014 than in 1984 and 2002. A keen comparison of the three maps shows more water enclosed within Ferguson's Gulf in Lake Turkana in 2002 than in 1984, and ultimately in 2014 than in the former two years.

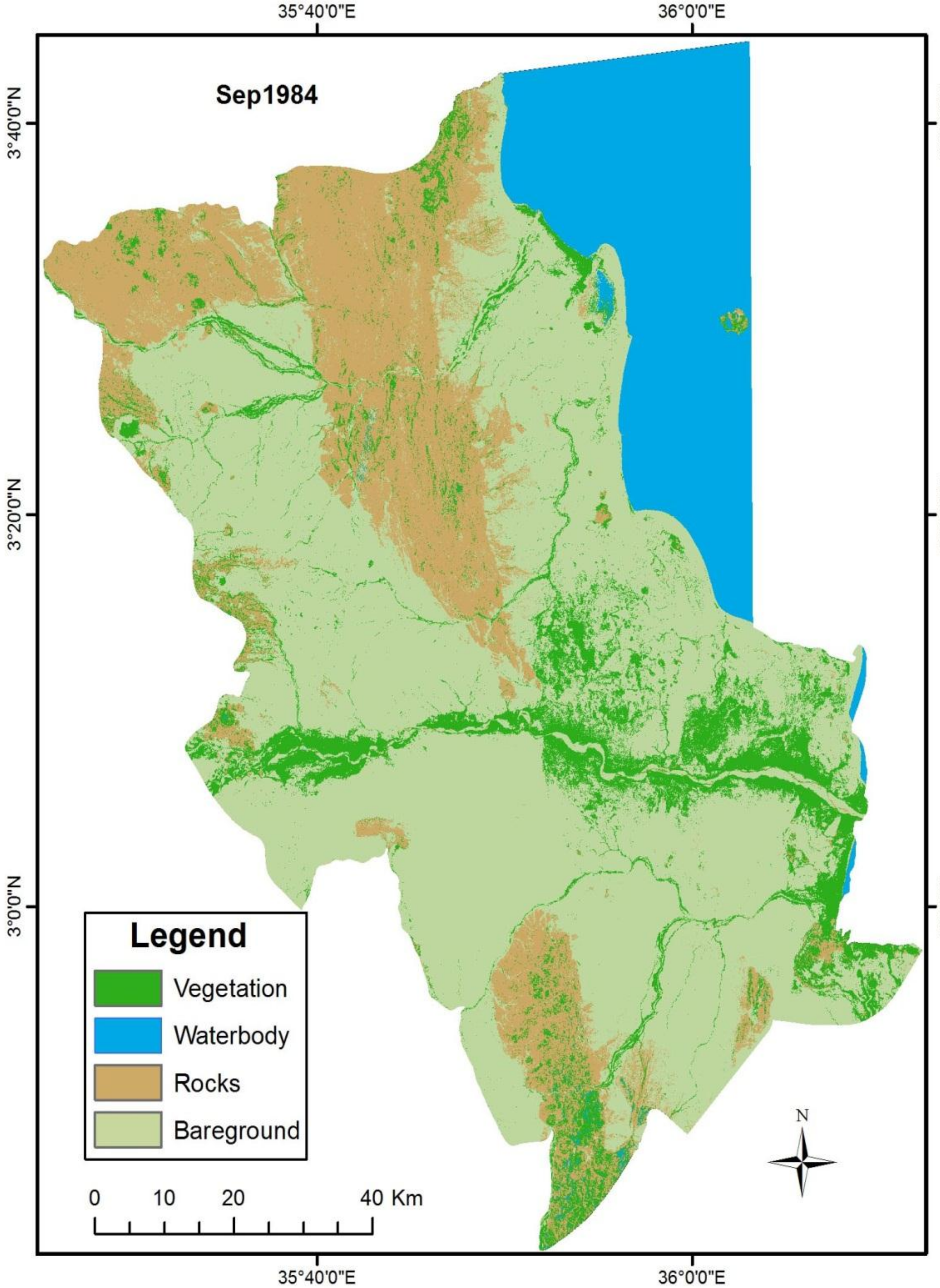


Figure 4.20: Land cover map for Turkana Central for September 1984

Source: Field data, 2015.

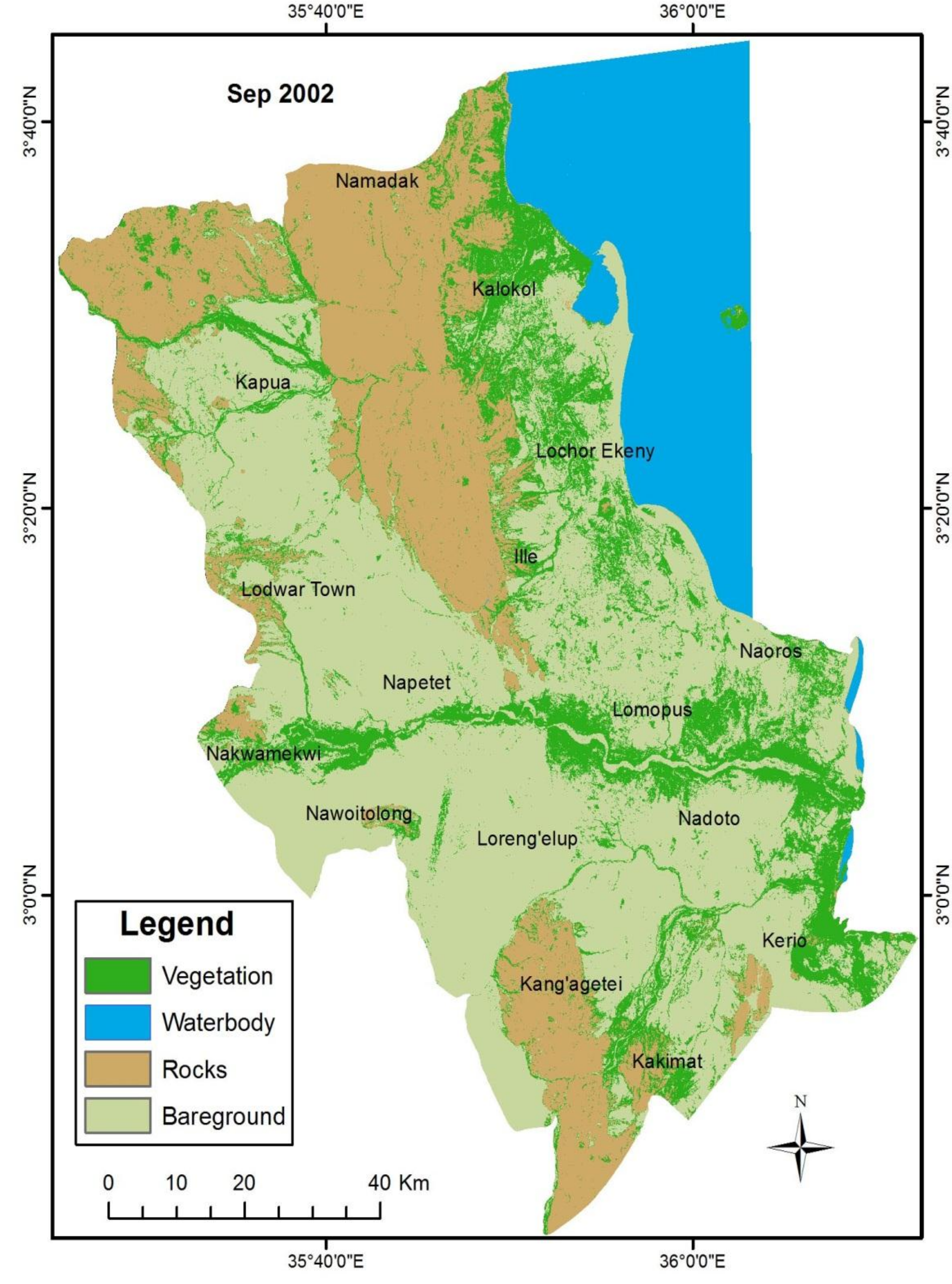


Figure 4.21: Land cover map for Turkana Central for September 2002

Source: Field data, 2015.

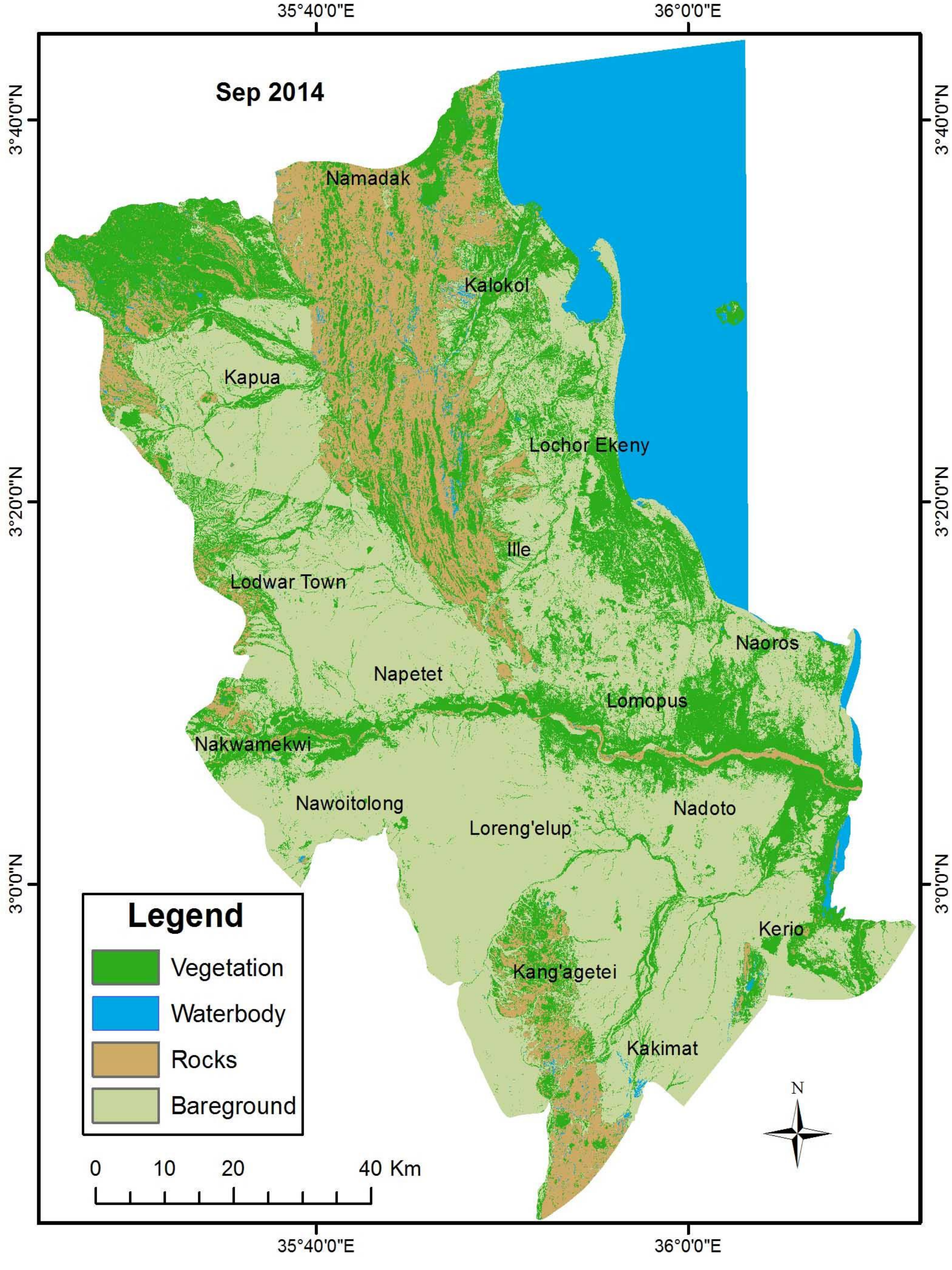


Figure 4.22: Land cover map for Turkana Central for September 2014

Source: Field data, 2015.

Generally, pasture and water availability had increased in Turkana Central over the period 1984 to 2014. Basing on the three maps (Figures 4.20, 4.21 and 4.22), surface areas under four classes were computed, as detailed in Table 4.14. Surface areas under both vegetation and water had registered a positive change.

Table 4.14: Surface areas covered by vegetation and water in the years 1983, 2002 and 2014

Class Type	1984 (Area km^2)	2002 (Area km^2)	2014 (Area km^2)	Δ Km^2 (2014-1984)	Change
Vegetation	613.4859	885.2040	931.4194	317.9335	Increased
Water body	793.8324	811.9503	854.3412	60.5088	Increased
Rocks	1030.8708	1157.2884	1131.0505	100.1797	Increased
Bare ground	2830.9095	2414.7342	2352.3658	- 478.5437	Decreased
TOTAL	5269.1769	5269.1769	5269.1769	000.0000	

Source: Field data, 2015.

4.6 Climate Variability and Pasture Availability Relationship in Turkana Central

The study sought to investigate the effects of rainfall and temperature variability on pasture availability. Spearman's correlation coefficient and Chi-square test were used to measure the level of association between changes in pasture availability and changes in rainfall amounts and temperatures, as perceived by respondents. The results are summarized in Tables 4.15 - 4.18.

Table 4.15: Correlation of rainfall variability and changes in pasture availability in Turkana Central

		Changes in rainfall amounts over the last 30 years	Changes in pasture availability over the last 30 years
Changes in rainfall amounts over the last 30 years	Correlation Coefficient	1.000	.701**
	Sig. (2-tailed)	.	.000
	N	100	100
Changes in pasture availability over the last 30 years	Correlation Coefficient	.701**	1.000
	Sig. (2-tailed)	.000	.
	N	100	100

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

Table 4.16: Cross tabulation between rainfall variability and changes in pasture availability over the last 30 years in Turkana Central

	Independent variable	
Dependent variable	Changes in rainfall amounts	
Changes in pasture availability	(χ^2)	131.622
	df	4
	sig.	0.000
	n	100

Pearson's Chi-square (χ^2) Degrees of freedom (df)

Rainfall variability had a moderately strong positive and significant effect on pasture availability over the last 30 years (r = 0.701; p< 0.00). With a decrease in rainfall amounts, there was a decrease in pasture availability, basing on the perception of the pastoralists interviewed. In a study conducted in Garissa County, 67 % of the respondents also indicated that increasing poor rainfall patterns resulted in a significant decline in pasture availability, greatly affecting livestock productivity in the region (Okoti *et al.*, 2014). In essence, rainfall is a major determinant of the quantity, quality and spatial distribution of natural pastures; unfavourable changes in rainfall patterns result in scarce, scattered and unpredictable pastures (ibid).

Table 4.17: Correlation of temperature variability and changes in pasture availability in Turkana Central

		Changes in temperature over the last 30 years	Changes in pasture availability over the last 30 years
Changes in temperature over the last 30 years	Correlation Coefficient	1.000	.217*
	Sig. (2-tailed)	.	.030
	N	100	100
Changes in pasture availability over the last 30 years	Correlation Coefficient	.217*	1.000
	Sig. (2-tailed)	.030	.
	N	100	100

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

Table 4.18: Cross tabulation between temperature variability and changes in pasture availability over the last 30 years in Turkana Central

	Independent variable	
Dependent variable	Changes in temperature amounts	
Changes in pasture availability	(χ^2)	4.791
	df	4
	sig.	0.309
	n	100

Pearson's Chi-square (χ^2)   Degrees of freedom (df)

Temperature variability, on the other hand, had a weak positive but insignificant effect on pasture availability over the last 30 years (r = 0.217; p< 0.309). The decrease in pasture could not be attributed to temperature changes, based on respondents' perceptions. Contrary to this, according to Hoang *et al.* (2014), the reported 0.7°C - 2.0°C increase in temperature in Kenya during the last 40 years has contributed to limited pasture growth in many arid-and semi-arid lands. High temperatures cause moisture loss from plants, due to high levels of evapotranspiration (Ute *et al.*, 2013).

Considering that there was a significant increase in rainfall amounts (160.7 mm) and a slight increase in temperatures (0.4°C) over the last three decades, as illustrated in Figures 4.1 and 4.7, pasture availability should have increased as well, holding other factors constant.

According to the land cover and NDVI maps, pasture availability had actually increased during the period 1984 to 2014. Pastoralists' perception of decrease in rainfall amounts and ultimately pasture availability can be attributed to the increasing frequency, and severity of droughts. In Kenya, droughts are the most significant and widespread manifestation of climate variability perceived by the indigenous communities, since they affect natural resources-based production systems like pastoralism (Ute *et al.*, 2012). The drought cycle in East Africa appears to be contracting sharply: rains used to fail every nine or ten years, then the cycle went down to five years and now the region is experiencing drought every two or three years (Campbell *et al.,* 2009). Turkana Central Livestock Department personnel corroborated that before 1990 the drought cycle of Turkana Central was predictable; after every 10 years there was a severe drought. However, between 1990 and 2014, the droughts became spontaneous, occurring after every 2 years. Village elders in Kapua location added that the duration between heavy rainfall episodes had increased resulting in severe droughts, unlike in the past. In 2009, Central Turkana experienced one of the worst droughts to ever hit the region, resulting in massive deaths of livestock and thus significantly undermining livelihoods (UN, 2012).

Changes in the frequency or magnitude of disturbance and covariance between perturbing factors, such as temperature and precipitation, may cause inevitable and irreversible vegetation changes (Hutyra *et al.,* 2005). Climate variability and change in the recent past has led to recurrent droughts, leading to water shortage and disruption of the vegetation cycle, thus causing a crisis for Turkana pastoralists (Ouma *et al*., 2012). The pastoralists confirmed that recurrent and severe droughts had a negative effect on pasture availability; grass virtually dried out during the dry seasons. According to Turkana Central Livestock Department personnel, a major drought in 2004 and 2005 resulted in migration of livestock from Turkana Central to Uganda, where there was sufficient forage. After sometime, conflicts arose over the water and pasture resources, forcing the Kenyan pastoralists to return. Since there was very little forage and water, both cattle and small stock were starved, got weak and eventually died. Consequently, there was food insecurity. For instance, the 1984 drought resulted in introduction of yellow maize in Turkana; that was the year relief emergency began. In addition, the Turkana Central Livestock Department personnel stated that the recurrent droughts led to migration of livestock to insecure areas in other regions of Turkana County; no-man-go zones (Turkana South and Loima). These regions usually had pastures because there was neither human nor livestock population. These are border points between the Turkana and Pokot communities.

On the other hand, floods occurring during the rainy season had minimal effects, as they were confined to areas along Lake Turkana and river courses. Though the 1997/1998 El Niño was severe, the Turkana Central Livestock Department personnel stated that it was beneficial to the Turkana community, as there were adequate pastures for livestock. However, the personnel further explained that livestock were drowned and swept away in 2006 and 2007 when Rivers Turkwel and Kauwalathe flooded their banks.

4.7 Climate Variability and Water Accessibility Relationship in Turkana Central

The other objective of the study was to assess the effect of rainfall and temperature variability on water accessibility. Hence, the relationship between changes in these two aspects of climate and water accessibility was measured using correlation and Chi-square, basing on respondents' perception. Tables 4.19 - 4.22 show the association.

Table 4.19: Correlation of rainfall variability and changes in water accessibility in Turkana Central

		Changes in rainfall amounts over the last 30 years	Changes in water accessibility over the last 30 years
Changes in rainfall amounts over the last 30 years	Correlation Coefficient	1.000	.925**
	Sig. (2-tailed)	.	.000
	N	100	100
Changes in water accessibility over the last 30 years	Correlation Coefficient	.925**	1.000
	Sig. (2-tailed)	.000	.
	N	100	100

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

Table 4.20: Cross tabulation between rainfall variability changes in water accessibility in Turkana Central over the last 30 years

	Independent variable	
Dependent variable	Changes in rainfall amounts	
Changes in water accessibility	(χ^2)	96.051
	df	4
	sig.	0.000
	n	100

Pearson's Chi-square (χ^2)   Degrees of freedom (df)

There was a very strong positive and significant relationship between rainfall variability and water accessibility over the last thirty years (r = 0.925; p< 0.000). The interviewed pastoralists had the perception that water accessibility decreased as the amount of rainfall received decreased over time.

Table 4.21: Correlation of temperature variability and changes in water accessibility in Turkana Central

		Changes in temperature over the last 30 years	Changes in water accessibility over the last 30 years
Changes in temperature over the last 30 years	Correlation Coefficient	1.000	.357**
	Sig. (2-tailed)	.	.000
	N	100	100
Changes in water accessibility over the last 30 years	Correlation Coefficient	.357**	1.000
	Sig. (2-tailed)	.000	.
	N	100	100

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

Table 4.22: Cross tabulation between temperature variability changes in water accessibility in Turkana Central over the last 30 years

Dependent variable	Independent variable: Changes in temperature	
Changes in water accessibility	(χ^2)	14.193
	df	4
	sig.	0.007
	n	100

Pearson's Chi-square (χ^2)   Degrees of freedom (df)

There was a moderate positive and significant relationship between temperature variability and water accessibility over the last thirty years ($r = 0.357$; $p< 0.007$). With an increase in temperatures, the pastoralists had the perception that there was a moderate increase in water accessibility.

Though pastoralists perceived that water accessibility had decreased with decrease in rainfall amounts received and increase in temperatures, water availability had apparently increased between the years 1984 and 2014, evidenced by the land cover maps (Figures 4.20, 4.21 and 4.22). With limited surface water and localized groundwater resources across arid and semi-arid lands in Kenya, pastoralists are heavily dependent on rainfall and rainwater storage for their livestock and domestic water needs (Dazé, 2013). However, water storage infrastructure is insufficiently developed in East Africa, with shortcomings being emphasized during natural disasters such as drought (EAC, 2011). Statistics by KNBS and SID on sources of water indicate that none of the residents in Turkana Central Sub-County harvested rainwater and only 0.2 % of the residents relied on dams (Ngugi *et al*., 2013). This means that, as much as more rainfall was received in the recent years, it ended up as surface runoff and underground water after infiltration; hence the increase in surface area under water bodies. The inadequacy of dams and other rainwater harvesting structures translated to low water accessibility despite increased water availability. In addition, of these water bodies, there are only three reliable water sources in the vast Turkana Central Sub-County – Lake Turkana, Rivers Turkwel and Kerio – that do not dry up during dry seasons. Consequently, not all pastoralists had adequate access to water for their livestock; only pastoralists herding their livestock within reasonable distance to the rivers fully utilized their waters. Ngugi *et al*.

(2013) substantiate this by stating that Lake Turkana and streams/rivers are sources of water to only 7.8 % and 17.5 % of residents in Turkana Central, repectively.

The increase in rainfall might appear to be good news for the arid and semi-arid Turkana, but the increasing temperatures result in a substantial increase in evaporation rates, likely to exceed any increases in precipitation (Osbahr *et al.*, 2006). Ultimately, water availability is expected to become more problematic in the future, particularly if current population trends are matched with increased water demand (Mude *et al.*, 2007). Water Resources Management Authority Lodwar Office personnel also stated that the waters have high fluoride content and, thus, cannot even be used for pasture irrigation. Lake Turkana water, for example, has unacceptably high fluoride levels, high content of sodium, chlorides and total dissolved solids (Avery, 2012). With increasing temperatures and thus higher evaporation rates, salinity levels rise, decreasing potability of the water. Lake Turkana is also the most saline of the Rift Valley lakes, with no outlet, reduced inflows and high evaporation; resulting into depositing of salt in the soil and capping on the surface (GOK, 2013). Besides the lakes water being saline, it has high amounts of silt and organisms, and is thus not fit for long periods of livestock watering (NEMA, 2009).

Communities in arid and semi-arid regions of Kenya have experienced prolonged droughts resulting in acute water shortages, given the cumulative effects over the span of several years (IOM, 2010). The pastoralists interviewed agreed that with the onset of recurrent and intense droughts, water accessibility for livestock had decreased during these seasons. Most water points dried up during prolonged droughts, thus, distances to water points increased. Livestock had to trek longer distances to watering points. Communities in Turkana and other arid and semi-arid counties in the Horn of Africa have to travel extremely long distances to reach the nearest water sources during droughts (World Bank, 2011). Livestock Department personnel added that during these seasons, animals were at times watered after 2 or 3 days and there were certain days the pastoralists could not access water. Kapua village elders further attributed the problem of water scarcity to underutilization of underground water due to inadequacy of funds to drill boreholes and poor plans on water projects by the government. The village elders added that there was no proper and adequate consultation during establishment of water projects, as only a few community members were consulted.

4.8 Adaptation Strategies to Rainfall and Temperature Variability in Turkana Central

Pastoralists, agro-pastoralists and other communities inhabiting Kenya's arid and semi-arid lands have for years been exposed to droughts, floods and other climate-related risks that negatively affected their livelihoods (Mude *et al.*, 2007). This has necessitated adoption of adaptation strategies to curb the resultant hardships. Pastoralists in Turkana Central were more affected by droughts than floods. Droughts affected an expansive area of the region. The effects of droughts are heightened because of the spatial coverage of this natural disaster (Raleigh *et al.*, 2008). On the other hand, only residents along Lake Turkana and on flood plains of rivers, especially Turkwel and Kauwalathe Rivers, felt the effects of floods. Hence, there were more adaptation strategies against droughts than floods.

4.8.1 Indigenous Adaptation Strategies

Indigenous peoples have over time developed traditional knowledge and strategies for adapting to changing habitat and resource conditions due to climate variability (Ute *et al.*, 2012). Application of indigenous knowledge in Turkana Central was told of by the Livestock Department personnel. Residents along the rivers interpreted the movement of frogs into the ground and salamanders from trees to the ground as a sign of the onset of rain. During the study, the pastoralists stated that they had adopted a number of indigenous adaptation strategies. All the respondents migrated with their animals to greener areas during droughts, to improve livestock feed quality. Diversification of livestock by species was undertaken by 77% of the respondents, herd adjustments by type of livestock by 26 %, and flock adjustment by age of livestock by 37 %. In the case of herd adjustment by type of livestock, animals were split into small herds, each comprising a different species, and grazed on separate lands. The same phenomenon was employed in flock adjustment by age of livestock; young and old livestock were herded separately. Herd splitting reduces the impact of droughts on total livestock holdings (Ouma *et al*., 2012). Eighty-three percent of the respondents sold their livestock to mitigate the effects of droughts and floods. Unlike the Maasai community members who practise extensive preservation of pastures (IOM, 2010), only 1 % of the pastoralists interviewed conserved pastures traditionally (Figure 4.23).

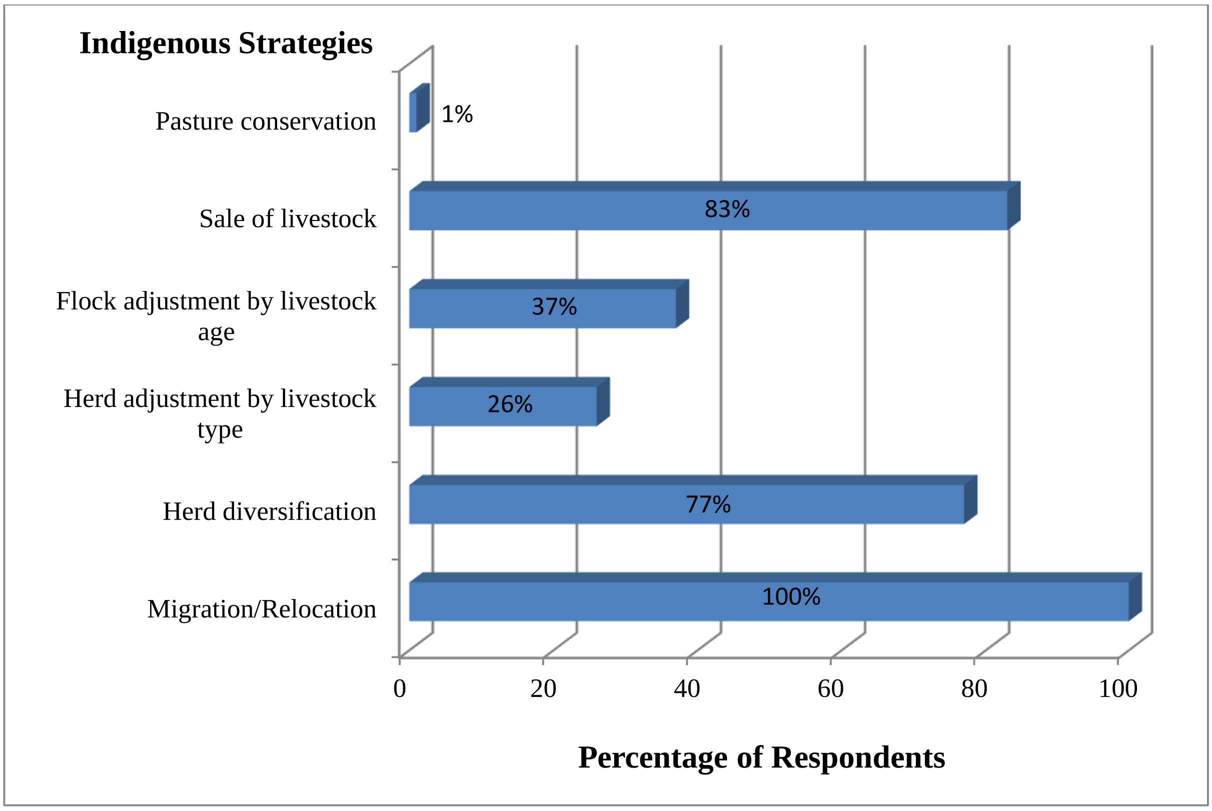


Figure 4.23: Indigenous adaptation strategies adopted in Turkana Central Sub-County

Source: Author's field survey, 2014.

An area where pastures were traditionally conserved was located at Kalotum, along the Lodwar-Kalokol road (Plate 4.8). Here deferred grazing was practised: the land was fenced off to allow grass and shrubs to grow during the wet season. Livestock, especially small stock, weak and lactating livestock, were then let in to graze during the dry season, when pastures were scarce. Similarly, in the traditional Somali grazing system, the rangeland was divided into areas for rainy season grazing, dry season grazing and areas reserved for grazing in the event of drought (Dazé, 2013).

Plate 4.8: Traditionally conserved pasture area in Kalotum, Turkana Central Sub-County

Source: Author’s field survey, 2014.

Mobility in marginal lands is crucial so as to rationally utilize natural resources and hence, have a minimal impact on these resources (Badege *et al*., 2013). Thus, migration has always been one of the most effective adaptation strategies against drought in pastoral communities (Zwaagstra *et al*., 2010). Livestock Department personnel stated that during drought, pastoralists moved to Loima Hills, Lorio Ranges, Turkana West or Turkana South; there were hardly any animals in Turkana Central during the dry season (January to March). Loima, Lorengippi, Mogila, Songot, Kalapata, Lorio, Kailongol and Silale ranges in Turkana County, because of their high elevation, are normally green, covered with dense bushes and high woody cover, thus, they are grazing grounds during the dry season (GOK, 2013). As discussed before, during the 2004 and 2005 drought, some pastoralists migrated with their livestock to Uganda in search of water and pastures. Similarly, during the 1999/2000 drought that led to severe shortage in water and pasture in Northern Kenya, Samburu and Borana herders and their livestock had to migrate to Meru in search of these natural resources (Campbell *et al*., 2009).

Pastoralists who could not move out of Turkana Central fed their animals on stored wild fruits (such as *Dobera glabra*, *Zizyphus mauritiana* and *Balanites orbicularis* fruits) and pods, mainly Acacia pods. According to Badege *et al*. (2013), leaves, pods, and fruits of many dryland tree and shrub species have a high content of protein and minerals, and are thus good sources of fodder during the dry season. Herd diversification was also a dominant strategy among the Turkana pastoralists. This pastoral strategy involves keeping a broad array of species (sheep, goats, cattle, camels and donkeys), which utilize different parts of the forage and thus have varying resistances to drought (Ouma *et al*., 2012). Other pastoralists resorted to having few numbers of animals to adapt to drought. The rich bought maize and fed it to the young and lactating livestock. The pastoralists also grazed their animals along the perennial River Turkwel, where there is riverine vegetation that does not dry up; most of the browse is available throughout the year because of water availability. Water Resources Management Authority Lodwar Office added that during the dry season, pastoralists excavated shallows wells, laggas, along seasonal rivers to obtain water for their animals. These laggas could even be three metres deep, as shown in Plate 4.9.

Plate 4.9: A lagga along River Kosiyae bed in Kapua Location, Turkana Central Sub-County

Source: Field survey, 15th August 2014.

During floods, people moved to high grounds, such as Nakwamekwi and Mborambui. When houses were swept away by floods, as was the case along River Kauwalathe, people relocated permanently. However, livestock were relocated temporarily. When floods were less severe, people relocated temporarily for about two days to one week.

The increasing frequency of climatic extremes and increasing unpredictability of weather patterns adds stress on already diminished coping strategies and limited adaptation mechanisms (Mude *et al.*, 2007). Turkana Central Livestock Department personnel concurred that the indigenous adaptation strategies were initially meant to offer short-term relief to pastoralists during the dry season, but with the increasingly spontaneous nature of droughts, some had become ineffective. The availability of wild fruits had decreased. With changes in climate, traditional sources of food become scarce and unpredictable (Okayo *et al.*, 2013). Migration, though effective, had seen changes; livestock still migrated to Uganda, Ethiopia & Sudan. In the past Turkana pastoralists used to migrate to Pokot, along the Turkwel Gorge, but have ceased because of enmity due to cattle rustling (Zwaagstra *et al*., 2010). In addition, the personnel stated that initially there was a bigger population of pastoralists moving with their animals. However, with the modern lifestyles, there were fewer people doing so in the recent past. The personnel projected that, with more children going to school and the population of human beings growing, migration may soon come to an end. There are areas that 10 years ago were not habited by human beings but now are. Migration is currently possible because of communal land ownership. The Livestock Department personnel added that the owner of Kalotum reserved pastures was fencing the land off, forecasting that in future more people might do so too, for the purposes of feeding fewer animals that will produce more milk and meat. They further stated that herd division, whereby sections of herds were grazed on different areas to reduce stress, was practised by a few during the study period unlike in the past. They attributed this to the decreasing number of animals reared, which could not be divided, due to the reduced drought cycle that constrained pastoralists from rebuilding their livestock herds' sizes.

4.8.2 Modern Adaptation Strategies

The Turkana pastoralists interviewed had adopted more water-related than pasture-related modern adaptation strategies. Only 2 % of the respondents provided hay for their livestock, 29 % feeding their animals with fodder crops and 1 % providing concentrates (such as dairy meal) as supplements for the natural forage. Water pans were accessed by 8 %, water tanks/tap by 29 %, and boreholes/wells by 28% of the household heads interviewed. Only 1 % of the respondents crossbreed their livestock with drought-tolerant breeds (Figure 4.24).

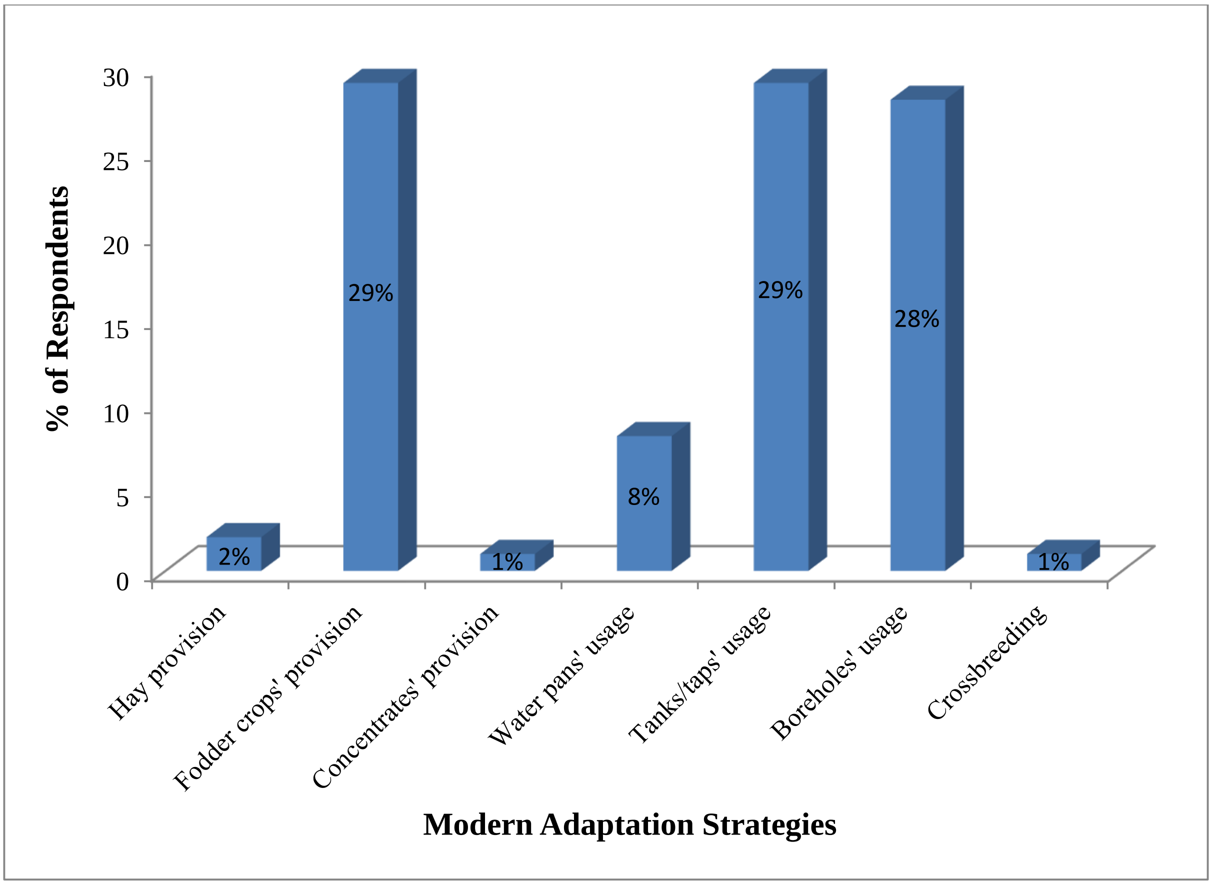


Figure 4.24: Modern adaptation strategies adopted in Turkana Central Sub-County

Source: Author's field survey, 2014.

Moderately fertile soils are found along Turkwel, Kauwalathe and Kerio rivers and along Lake Turkana at the lower Kalokol (GOK, 2013). These rivers occasionally flood after heavy rainstorms, depositing sediment into the river plains that are then cultivated (Ute *et al.*, 2012). Thus, fodder production was practised along the riverine areas, especially along these perennial Turkwel and Kerio rivers, such as in Nakwamekwi Village in Lodwar Township. Livestock fed on napier grass, sugarcane, sweet potato vines and stovers of sorghum (Ngakasirim) and maize after these are harvested. With fodder production, many animals could be fed in a smaller area compared to natural grazing. Plates 4.10 – 4.18 illustrate some of these modern adaptation strategies and the accompanying structures.

Plate 4.10: Cattle feeding on napier grass in Kanamkemer Location, Turkana Central

Source: Author's field survey, 16th August 2014.

Plate 4.11: Sugarcane used as forage at Nakwamekwi Village, Turkana Central Sub-County

Source: Author's field survey, 2014

A well-maintained farm by St.Teresa Parish, along River Turwel, at Nakwamekwi Village grew flourishing crops: maize, bananas, sweet potatoes, egg plants and pawpaws. In addition to the sweet potato vines and maize stovers, banana leaves and pseudostems (stalks/trunks) were used as nutritious fodder for especially cattle, goats and sheep during the dry seasons. Plates 4.12 and 4.13 give a pictorial illustration of the green St.Teresa Parish farm.

Plate 4.12: Maize and banana plantation at Nakwamekwi Village, Lodwar Township, Turkana Central Sub- County

Source: Author’s field survey, 2014.

Plate 4.13: Sweet potato forage at Nakwamekwi Village, Lodwar Township, Turkana Central Sub-County

Source: Field survey, 2014.

Oxfam, among other stakeholders in Turkana, invested in more long-term water infrastructural development, such as shifting from diesel-powered boreholes to solar-powered ones (Oxfam, 2012). A similar water pump, located a few metres from the Turkwel River at Kang'agetei Village, is illustrated in plate 4.14. Another pump that used a renewable source of energy, wind, was used to draw water (Plate 4.15). In most regions, however, most of the pumps were manually-operated (Plate 4.16).

Plate 4.14: Sorghum fodder crops and a solar-powered water pump at Kang'agetei Village, Kang'atotha Location, Turkana Central Sub-County

Source: Author's field survey, 2014

Plate 4.15: A windmill at Nakwamekwi Village, Turkana Central Sub-County

Source: Author's field survey, 16th August 2014

Plate 4.16: A manual water pump in Najakasikiria Village, Napetet Location, Turkana Central Sub-County

Source: Author's field survey, 2014.

Water Resources Management Authority provided plastic tanks through Water Resources Users Associations. The pastoralists, especially those living away from the perennial rivers, relied on these tanks to water their small stock that did not migrate during droughts. Plate 4.17 gives an illustration of Turkana women and children assembling to draw water from a tank at Nachamae Village in Kapua Location.

Plate 4.17: A water tank at Nachamae Village, Kapua Location, Turkana Central Sub-County

Source: Author's field survey, 15th August 2014.

Water pans, which would be very useful to water animals during the dry season, dried up in some areas. The Livestock Department personnel gave an example whereby, on their way from Uganda during the 2004/2005 drought, pastoralists lost many livestock as Nalapatui water pan, which they expected would have some water, was dry. Plate 4.18 below gives an illustration of yet another case. A water pan in Kalotum, a few metres off the Lodwar-Kalokol road, was dry in August 2014 - during the study period.

Plate 4.18: A dry water pan in Kalotum, Turkana Central Sub-County

Source: Author's field survey, 2014.

The Livestock Department in Turkana Central, in response to the frequent severe droughts, had introduced four modern strategies. The first strategy, *pasture fields' establishment*, involved encouraging farmers to grow grass, harvest and store it for use as fodder during the dry spell. To implement the second strategy, *holding ground strategy*, the department had acquired 3,000 acres of land, where it would grow pastures. During drought, weak animals would be let in to graze on these pastures. *Strategic feed reserves strategy* was the third intervention introduced by the Department, whereby forage was planted during the wet season, which would be harvested and stored for distribution to pastoralists during drought. Since insufficient forage and inbreeding depression had resulted in smaller-sized animals and reduced reproduction, the implementation of the fourth intervention, *livestock breeding and multiplication centre strategy,* was in progress. The department was establishing a centre to upgrade livestock to high-yielding and drought-tolerant breeds. In this centre, the department would also grow forage, which when in excess would be sold or given to pastoralists.

4.8.3 Adaptation Constraints in Turkana Central Sub-County

Most factors inhibiting adoption of both the indigenous and modern adaptation strategies in Turkana Central were related to low literacy levels and low income in the region. Sixty-three percent of the household heads interviewed could not adopt some adaptation strategies because of lack of skills, capital, tools and facilities. Twenty-seven percent of the respondents were inhibited by lack of skills, knowledge and capital, 7 % by lack of skills and capital and 3% by lack of capital/funds. Figure 4.25 summarizes these results.

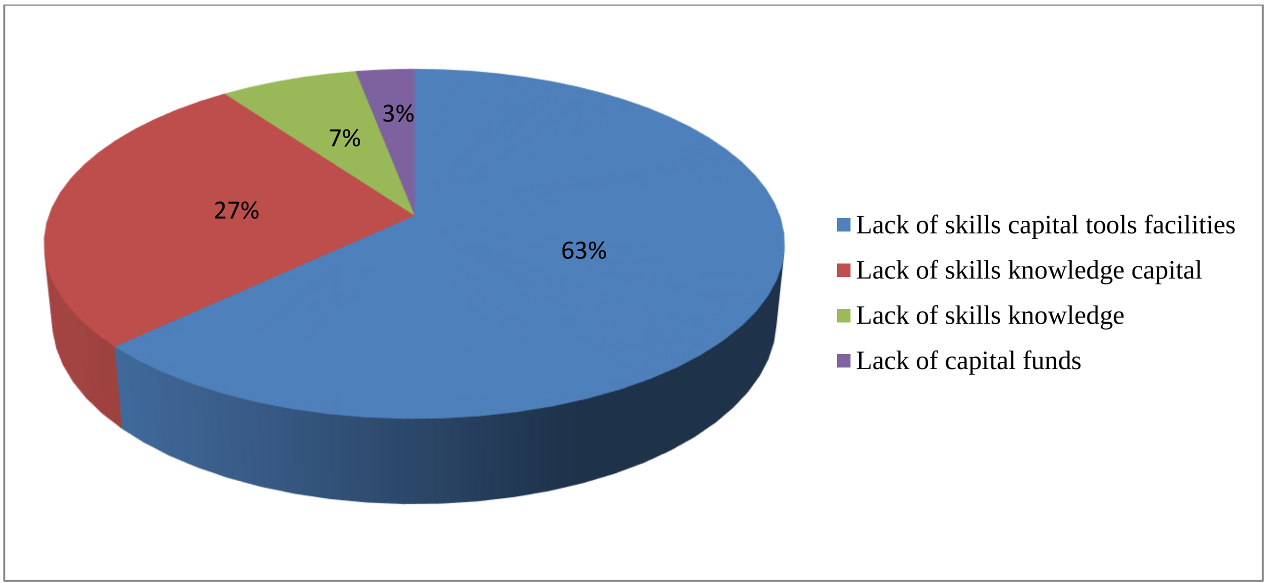


Figure 4.25: Constraints hindering adoption of adaptation strategies in Turkana Central

Source: Author's field survey, 2014.

These results were in agreement with respondents' perception of people most affected by climate variability. Of all the respondents interviewed, 78 % cited that the poor bore the brunt of climate variability. Hydro-meteorological hazards such as droughts and floods afflict many regions of the world, but their effect in terms of livelihoods disrupted and lives lost is greater on the poor in developing countries (Osbahr & Viner, 2006). The effect of drought is particularly acute for poor people with smaller livestock holdings and less developed social support networks (Ouma *et al*., 2012). According to 59 % of the respondents, the poor depended mainly on the few livestock they own, which when killed during droughts and floods, these poor people become adversely affected. Fifteen percent of the respondents cited dependence by the poor on organizations, including Oxfam, World Vision, Red Cross and

Medical Emergency Relief International (MERLIN), as the reason of vulnerability to climate variability.

Ministry of Agriculture and Livestock Department officers concurred that dependency syndrome was a very significant factor contributing to low adoption of adaptation strategies. The officers elaborated that the Turkana community members were very reluctant to adapt because of assurance of relief aid in the event of a drought or flood, from the government or Non Governmental Organizations. In some instances there were cases of prolonged relief, such as the Emergency Food Operation, which was introduced during the 2005 and lasted till 2010. Relief is becoming a near permanent feature in Turkana, due to the increasingly frequent and severe climate floods and droughts that have translated into persistent emergency situations in the region (Ute *et al.*, 2012).

The Livestock Department personnel attributed the lack of technical know-how by pastoralists in Turkana Central to the low number of extension officers and schools in comparison to the vastness of the region. Hence, the few officers were not in a position to reach most of the areas, making information dissemination difficult. This, they added, was compounded by poor transport and terrain and insecurity in Kerio, Lorio Hills and Kang'erisai (at the border of Turkana Central and Turkana East Sub-counties).

According to Ministry of Agriculture and Livestock Department officers, communal land tenure system acted as a disincentive for development, such as agro-forestry. As a result, the officers noted that there was high livestock concentration along the communal riverine areas especially during the dry season, as pastoralists sought to feed their livestock on stovers of crops grown along the rivers and grasses and weeds that grow within the farms.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Chapter Summary

The purpose of this study was to assess the effects of climate variability on pastoralism and adaptation strategies in Turkana Central, Kenya. This chapter therefore, presents the key findings of the study, the conclusions drawn from these findings and the recommendations to improve pastoralists' resilience to the greatly varying climate. Lastly, a section on recommendation for further research is given, highlighting a research gap.

5.2 Key Findings and Conclusions

The key findings of the study were:

i) In Turkana Central, there was a general increase in rainfall amount and variability from the year 1983 to 2014. The amount of rainfall received had increased by 160.7 mm over the period. However, the frequency and severity of droughts had increased; the drought cycle had reduced from 10 years to 2 years. On the other hand, there were slight changes in temperature, an increase of 0.4°C, during the same period.

ii) Pasture availability in Turkana Central had increased as rainfall amounts increased and temperatures remained relatively the same. The mean Normalized Difference Vegetation Index (NDVI) values in the year 1984 and the year 2014 were 0.262 and 0.377, respectively, corresponding to increasing shrub and grassland vegetation. In addition, the surface area covered by vegetation had increased by 317.9 km^2: from 613.5 km^2 in year 1984 to 931.4 km^2 in the year 2014. Notwithstanding, pastoralists trekked longer distances in search for pastures during drought in the recent years than in 1980s, due to drought severity. The distance covered during the rainy seasons was relatively the same over the three decades.

iii) Water availability also increased as rainfall amounts increased and temperatures remained relatively the same, though 49 % of the respondents stated that water accessibility had decreased. In Turkana Central Sub-County, the surface areas covered by water in the years 1984 and 2002 were 793.8 km^2 and 811.95 km^2, respectively. In the year 2014, this area had further increased to 854.3 km^2, giving a total increase of 60.5 km^2 since the year 1984.

iv) Among the indigenous adaptation strategies, migration was the most commonly practised, with pastoralists moving to Loima Hills, Lorio Ranges, Turkana South and Uganda during droughts. The pastoralists also diversified their livestock, sold their livestock during drought, grazed animals along riverine areas and excavated laggas. On the other hand, the pastoralists had adopted more water-related than pasture-related modern adaptation strategies. In terms of pasture-related strategies, focus was on fodder crops grown along the flood plains of the perennial Turkwel and Kerio Rivers. Water-related modern adaptation strategies ranged from usage of boreholes, water tanks and taps to water pans.

From the study findings, the following conclusions were drawn:

i) Climate is becoming more variable, with time, in Turkana Central Sub-County. Rainfall patterns are becoming more erratic; rainfall is unreliable. On the other hand, temperatures are increasing gradually.

ii) Increasing variability in climate has led to increase in pastures, notably along water bodies. However, unlike in the past, severe pasture scarcity is experienced during droughts, which are becoming more recurrent, intense and prolonged.

iii) Climate variability has resulted in increase in water availability in water bodies. Nonetheless, this increase does not translate to increased water accessibility, considering that evaporation rates have increased, there are very few rainwater harvesting structures and only three permanent and perennial water sources – Lake Turkana, Rivers Turkwel and Kerio – in the vast Turkana Central Sub-County.

iv) Migration and herd diversification remain the most effective indigenous adaptation strategies, as droughts become more frequent. Whereas water pans' usefulness is liable to climatic conditions, fodder provision and usage of boreholes and water tanks offer relief during droughts; being the widely adopted modern adaptation strategies.

5.3 Recommendations

The researcher therefore puts forth these recommendations:

i) More meteorological stations should be established within study area and modern ways of collecting data used. This would ensure that the inferences made, based on averages, are representative of the entire area and data is comprehensive – no data is missing.

ii) Agro-forestry should be practised, especially during the wet season, in order to maximize the utilization of rainwater. The fodder crops will be used as livestock feed during droughts, thus minimizing number of livestock deaths due to starvation.

iii) Increased water availability due to increased rainfall amounts should be tapped into. Rainwater harvesting and distribution infrastructure and technologies should be implemented intensively and expansively in Turkana Central Sub-County.

iv) Indigenous adaptation strategies, which have been neglected, should be integrated into modern adaptation strategies. The use of traditional knowledge should be reinforced to support the existing modern early warning systems on predicted drought and floods.

Generally, proactive community capacity building programmes should replace the reactive humanitarian aid programmes. Pastoralists should be in a position to survive independently during droughts and floods; they should not rely on donor agencies and well wishers for assistance. In order to curb this widely spreading dependence syndrome, relevant authorities with jurisdiction over the region should educate more pastoralists on the importance of adopting sustainable modern adaptation strategies.

Recommendation for Further Research

Research on drought-tolerant tree and shrub species that grow well on soils within the study area should be undertaken vigorously, and more of such trees planted in the region. These trees would provide nutritious fodder for animals during the dry season, especially the young, weak and lactating animals that cannot move to distant favourable lands to access pastures. Subsequently, the pressure on riparian vegetation during dry seasons, due to concentration of livestock, would be substantially reduced. In addition, the tree roots would enhance the soil's water-holding capacity, by increasing the adhesiveness of soil particles. Ultimately, pastures would remain green longer when dry seasons set in, availing forage for livestock.

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APPENDICES

APPENDIX I: QUESTIONNAIRE

The researcher is a master's student of Environmental Science at Egerton University. The aim of administering this questionnaire is to understand the effects of climate variability on pastoralism and the adaptation strategies in Turkana Central Sub-County. Kindly respond to the following questions. Your assistance will be highly appreciated.

All information given will be treated with utmost confidentiality.

SECTION A: Background information

1. Division …………………. Location ………………….Village ………………………

For the following questions tick where appropriate

2. Are you originally from this division? A. Yes [ ] B. No [ ]
3. Respondent's gender A. Male [ ] B. Female [ ]
4. Age bracket (in years) A. 40-50 [ ] B. 51-61 [ ] C. 62-72 [ ] D. 73-83 [ ]
5. Level of education A. None [ ] B. Primary [ ] C. Secondary [ ] D. Tertiary [ ]
6. Number of family members A. 0-6 [ ] B. 7-13 [ ] C. 14-20 [ ] D. 21-27 [ ]

For the following questions answer as sincerely as possible

7. Family income, in Kenya shillings, earned from livestock keeping per year
   A. 1000-50,000 [ ] B. 51,000-100,000 [ ] C. 101,000-150,000 [ ] D. 151,000-200,000 [ ] E. 201,000-250,000 [ ] F. 251,000-300,000 [ ] G. 301,000-350,000 [ ] H. 351,000-400,000 [ ] I. 401,000-450,000 [ ] J. 451,000-500,000 [ ]
8. Which would you say is your most important source of income? A. Livestock [ ]
   B. Charcoal selling [ ] C. Other (specify) [ ] ………………………………….
9. What type of animals/livestock do you raise?
   A. Cattle [ ] B. Goats [ ] C. Sheep [ ] D. Camels [ ] E. Donkeys [ ]
10. How you made any changes in the type of livestock you raise? Yes [ ] No [ ]
    If Yes, from …………………..……………. to …………………………………….
11. Which type of forage/fodder do your livestock mainly feed on?
    A. Grass [ ] B. Shrubs [ ] C. Tree leaves [ ] D. Hay [ ] E. Others……......
12. Which is the primary source of water for your livestock? A. Rivers [ ] B. Laggas [ ]

C. Wells/boreholes [ ] D. Water taps [ ] E. Others ………………………………

SECTION B: Community's Perception on Climate Variability

13. Have you noticed any changes in temperatures in the region over the last 30 years?
    A. Yes, increased [ ] B. Yes, decreased [ ] C. No [ ]
14. Have you noticed any changes in rainfall amount in the region over the last 30 years?
    A. Yes, increased [ ] B. Yes, decreased [ ] C. No [ ]
15. Have incidences of floods increased during the raining seasons over the last 30 years?
    A. Yes [ ] B. No [ ]
    If yes, during which month(s) ……………………………………………………………..
16. Have droughts become prolonged over the last 30 years? A. Yes [ ] B. No [ ]
    If yes, from being ……………………….… months to …….…………...…… months long
17. Have you noticed any changes in pasture availability in the region over the last 30 years?
    A. Yes, increased [ ] B. Yes, decreased [ ] C. No [ ]
18. How far was the grazing area for your livestock during rainy seasons, 30 years ago?
    A. 0 – 1 km [ ] B. 2 - 3 km [ ] C. 4 – 5 km [ ] D. 6 – 7 km [ ] E. 8 - 9 km [ ]
19. How far do you trek to reach the grazing area for your livestock during rainy seasons?
    A. 0 – 1 km [ ] B. 2 - 3 km [ ] C. 4 – 5 km [ ] D. 6 – 7 km [ ] E. 8 - 9 km [ ]
20. How far was the grazing area for your livestock during droughts, 30 years ago?
    A. 0 – 4 km [ ] B. 5 - 9 km [ ] C. 10 – 14 km [ ] D. 15 – 19 km [ ] E. 20 - 24 km [ ]
21. How far do you trek to reach the grazing area for your livestock during droughts?
    A. 0 – 4 km [ ] B. 5 - 9 km [ ] C. 10 – 14 km [ ] D. 15 – 19 km [ ] E. 20 - 24 km [ ]
22. Have you noticed any changes in water accessibility in the region over the last 30 years?
    A. Yes, increased [ ] B. Yes, decreased [ ] C. No [ ]
23. How far was the water source for your livestock during the rainy seasons, 30 years ago?
    A.1 – 250 m [ ] B. 251 – 500 m [ ] C. 501 – 750 m [ ] D. 751 – 1000 m [ ]
    E. 1001 – 1250 m [ ] F. 1251 – 1500 m [ ] G. 1501 – 1750 m [ ] H. 1751 – 2000 m [ ]
24. How far is the water source for your livestock/animals during the rainy seasons?
    A.1 – 250 m [ ] B. 251 – 500 m [ ] C. 501 – 750 m [ ] D. 751 – 1000 m [ ]
    E. 1001 – 1250 m [ ] F. 1251 – 1500 m [ ] G. 1501 – 1750 m [ ] H. 1751 – 2000 m [ ]
25. How far was the water source for your livestock during droughts, 30 years ago?
    A. 0 – 1 km [ ] B. 2 - 3 km [ ] C. 4 – 5 km [ ] D. 6 – 7 km [ ] E. 8 - 9 km [ ]
26. How far is the water source for your livestock/animals during droughts?
    A. 0 – 1 km [ ] B. 2 - 3 km [ ] C. 4 – 5 km [ ] D. 6 – 7 km [ ] E. 8 - 9 km [ ]

27. Does the environment suffer from excessive loss of vegetation? A. Yes [ ] B. No [ ]

If yes, why? ……………………………………………………………………………….

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

28. Who are the people most affected by climate variability? A. The poor [ ] B. The rich [ ]

Explain your answer; why ……………………………………………………………………….

…………………………………………………………………………………………………

…………………………………………………………………………………………………

SECTION C: Livestock-related Adaptation Strategies

29. Do you employ the following indigenous adaptation strategies to droughts and floods?

Indigenous Adaptation Strategy	**Yes or No**
Relocation (moving livestock to favourable areas)	
Diversification of livestock by species	
Herd/flock adjustments by type/species	
Herd/flock adjustments by age	
Sale of livestock/animals	
Using traditional pasture conservation methods	

30. Do you employ the following modern adaptation strategies during droughts and floods?

Modern Adaptation Strategy	**Yes or No**
Hay provision	
Fodder crops' provision (e.g. napier grass, lucerne, oats)	
Dairy meal and other concentrates' provision	
Water pans usage	
Water tanks/tap usage	
Borehole/well usage	
Crossbreeding livestock with drought-tolerant varieties	

If your answer is "No" to any of the adaptation strategies in question 29 and 30 above, kindly answer question 31 below.

31. Please give any constraints or reasons why you could not use the indigenous and modern adaptation strategies stated above

    1) ………………………………………………………………………………………
    2) ………………………………………………………………………………………
    3) ………………………………………………………………………………………
    4) ………………………………………………………………………………………
    5) ………………………………………………………………………………………

Thank you for your cooperation and assistance.

APPENDIX II: FOCUS GROUP DISCUSSION QUESTIONS

The researcher is a master's student of Environmental Science at Egerton University. The aim of conducting this focus group discussion is to understand the effects of climate variability on pastoralism and the adaptation strategies in Turkana Central Sub-County. Kindly respond to the following questions. Your assistance will be highly appreciated.

1. In your opinion, has climate variability been experienced in the region? If "yes", can you remember any major climate-related extreme events such as droughts or floods that may have occurred in the period between 1983 and 2014?
2. What were the effects of these climate-related extreme events on the pastoral livelihoods, in terms of pasture availability and water accessibility?
3. In your own view, does the local community have a clear understanding of climate variability?
4. In view of the enumerated events, what did the community, out of their own indigenous knowledge, do in order to adapt to the climate shocks? Dwell on livestock-related strategies.
5. What livestock-related modern/scientific adaptation strategies have local authorities whose area of jurisdiction cover the study area introduced to mitigate the effects of climate variability?
6. In your view, how effective are the indigenous and modern adaptation strategies in mitigating the effects occasioned by the events?
7. In your view, how have the enumerated livestock-related adaptation strategies changed since 1983 to 2014?
8. Can you identify any constraints the community faces that may prevent them from gaining the most from the indigenous and modern adaptation strategies?
9. Can you identity any constraints the community faces that prevents them from gaining the most from the utilization of water resources, such as Lake Turkana, River Turkwel, seasonal rivers and underground water?
10. Are local community members consulted before the implementation of the water resource projects within the region? If "yes", what is the type and level of community involvement?

Thank you for your cooperation and assistance.